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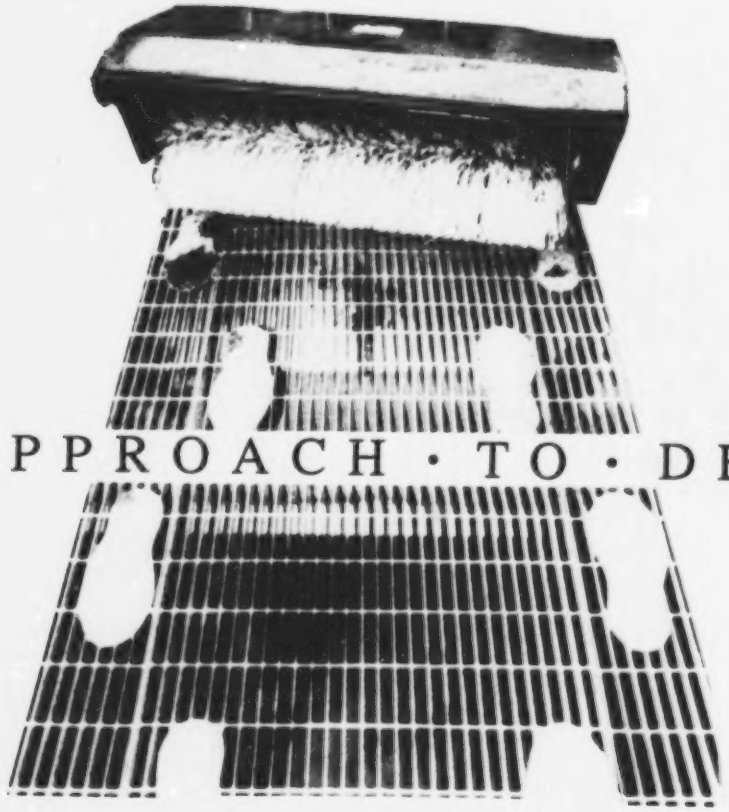

AN · APPROACH · TO · DESIGN

FOR

W * I * N * T * E * R

CALGARY:

An Approach to Design for Winter

Researched, written and illustrated by

ELEMENTAL DESIGN GROUP

Faculty of Environmental Design

The University of Calgary

for The World Winter City Committee of the City of Calgary

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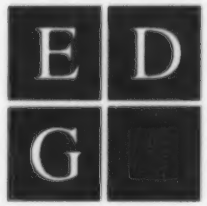

EXECUTIVE SUMMARY

Calgary: An Approach to Design for Winter is intended for anyone involved in shaping built environments in Calgary. One does not need to be a design professional or directly involved in the building industry to understand and benefit from this information.

This manual describes Calgary's winter climate and provides recommendations for planning and designing buildings and open spaces in this winter city. The information is presented in two main sections: **Awareness** and **Design Guidelines**. Rather than attempting to provide a comprehensive source of winter design solutions, we have chosen to outline the major design considerations and present some solutions that are appropriate for Calgary. We hope the document will serve as a catalyst for the development of new and innovative architectural environments that are suited to this winter city.

AWARENESS

The first chapter of the **Awareness** section contains a summary of the macroclimate of the Calgary region, followed by a discussion of mesoclimatic variations. The modifying influences of Calgary's urban forms on the climate are discussed in the second chapter.

Climate

Three main weather systems affect the Calgary region:

1 Chinooks bring unseasonably warm temperatures and strong westerly winds.

2 Arctic air masses deliver cold temperatures, northerly winds and high wind-chill factors.

3 Southerly air masses bring above average temperatures, light southerly winds and Calgary's largest snowfalls.

The four climatic factors that need to be considered for winter design in Calgary are temperature, wind, sun and precipitation. The large variability of temperature and wind are explained by the three main weather systems affecting Calgary in winter. Sun is common in Calgary during the winter, occurring during nearly 50% of daylight hours; however, daylight hours are short (8-10 hours) and sun angles are low (maximum December sun angle is 16°). Calgary receives annual snow accumulations (150 cm) comparable to other Canadian winter cities. However, snow cover is variable due to periodic Chinooks and mild Pacific air masses.

There are four characteristic landforms in Calgary. These are River Valleys, Lowlands, Border Uplands and Bedrock-Cored Hills. River Valleys channel winds parallel to their orientation while shielding winds perpendicular to valley orientations. Broadcast Hill and Nose Hill are the only examples of Bedrock-Cored Hills in the Calgary region and are exposed to the highest winds in the Calgary region. Border Uplands, located on the flanks of Bedrock-Cored Hills, have relatively uniform aspects and consequently uniform sun exposures. Bedrock-Cored Hills moderate wind speeds and influence sun exposure in surrounding areas.

Urban Form

The five main types of urban form occurring in Calgary are the **downtown core** located in River Valleys; **industrial areas** and **inner city residential areas**, both located in River Valleys and adjacent Lowlands; **"City Beautiful" residential areas** located in Lowlands; and **cellular residential areas** found in all Landform units. The north-south east-west oriented grid street pattern found downtown, in industrial areas and inner city residential areas tends to channel westerly and northerly winds. The downtown core severely limits sun penetration and contributes to strong wind gusts. Cellular street patterns are more effective at moderating wind velocities and preventing extensive channelling than are grid street patterns.

The temperature inversions during elevated Chinooks result in easterly winds carrying pollutants from industrial areas, limited atmospheric mixing and a consequent decline in air quality conditions in River Valley and Lowland areas.

DESIGN GUIDELINES

The Design Guidelines section contains a discussion of aspects of winter that affect Calgary's built environment and provides solutions to some of the problems described. This section has been organized into four chapters to reflect different levels of design intervention ranging from the large contextual view to specific details.

Building Configuration contains ideas about the design and siting of individual buildings in the urban environment. The **Relationship between Built Forms** chapter examines how climate can be influenced by groups of buildings. In the **Relationship of Building to Street** chapter, design solutions specific to the relationship of buildings and their surrounding open space are addressed. The final chapter, **Building Details**, focuses on enhancing the performance of some building components and hardware in winter.

Building Configuration

The Building Configuration chapter discusses the legal requirement for wind tunnel testing of proposed buildings to determine wind effects on pedestrians. The aerodynamics of wind flow, in relation to the height and exposure of building faces, are presented. The problems of downwash and vortex are explained. Some solutions to building-induced wind turbulence are provided in the discussion of Building Shape and Massing. They include placing a building on a

podium, designing circular or pyramidal configurations, and turning a building 45 degrees. The Siting discussion integrates wind and solar considerations, emphasizing the importance of optimizing sunlight penetration and minimizing wind effects.

Relationship between Built Forms

This chapter deals primarily with wind and solar access characteristics in relation to the size, shape, orientation and spacing of buildings. The problems of wind effects like the Venturi effect, the channelling effect, drifting and eddying are explained. The two categories of responses to pedestrian wind problems are enclosing and eliminating pedestrian activity. The need for solar access is explained. Sunlight, shadow and wind all have an effect on snow accumulation and melting.

In the discussion about Low Density Urban Areas, recommendations are made for maximizing the benefits of sun, such as increasing the area of southern windows, having light-reflective interior surfaces and using thermal masses that absorb heat.

Relationship of the Building to Street

Landscaping considerations provide the focus for this chapter. Ideas are discussed that influence wind, sun, precipitation and temperature. The use of plants to intercept, direct and lessen the wind is described. Suggestions include planting shelter belts, using conifers, optimal height to length ratios for wind breaks, glare control and control of ice build-up. The discussion of Street Access And Servicing points out how landscaping and orientation affect driveways, service areas, sloped access and pedestrian access corridors.

Building Details

The final chapter features solutions for four major design areas: entrances, doors, windows and roofs. Entrances can be sheltered by fully or partially recessing them, or by using sheltering or deflecting walls, canopies or corner locations. Pedestrian ramps can be modified to suit the climate by using snow melt gutters, heat absorbing materials, half walls, non-slip surfaces and handrails. Illumination can be artificial or enhanced natural light. Doors present a heat loss problem but can be designed to minimize heat loss. Revolving and air lock entry vestibules control heat loss. Windows should be designed to optimize, not maximize, sun exposure and solar penetration. Roofs are susceptible to snow build-up problems and can be designed to avoid settlement on lower structures adjacent to higher ones by reducing projections on flat roofs, reducing roof pitch to prevent falling snow and insulating to minimize melting.

SUGGESTIONS FOR FURTHER WORK

The Awareness section could include more climatic data and information about cultural adaptations. Research to characterize general windflow patterns or trends within the city would permit new developments to more effectively consider wind as a design constraint. The Design Guidelines could be expanded upon with recommendations for designing for specific building typologies (e.g., institutional or commercial buildings). The needs of different user groups, such as children or senior citizens, could be addressed. Design criteria and solutions for urban spaces, parks, plazas, streets, street furniture, signage, illumination and road maintenance could be developed further.

USE OF THIS MANUAL

The information in the manual can be accessed in a variety of ways, including of course, reading the manual from cover to cover.

The Awareness section can be read to identify specific climatic problems of a potential building site. The reader can then refer to the appropriate parts of the Design Guidelines section.

Should the reader have specific questions about building details or other aspects of design such as landscaping, or building configuration it would be expedient to refer directly to that section.

This Executive Summary provides an overview of the information contained in the manual. The reader could refer to it for an indication of where relevant information is located.

The illustrations highlight points in the text. They can be referred to independently of the text or prior to reading the text for more detailed information. Headers on each page indicate the main topics that are addressed.

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CLIMATE

URBAN FORM

AWARENESS

INTRODUCTION

Calgary's climate can be considered in two ways. The macroclimate or overall climate of Calgary is controlled by its geographic location, regional atmospheric circulation and proximity to the mountains. The mesoclimate or climatic variability within Calgary is controlled by local topography and urban form.

Human comfort in the outdoors is primarily determined by temperature, sunlight and wind. Large accumulations of snow can also affect the movement of pedestrians and vehicles. These conditions can be exacerbated or mitigated by buildings and landscaping. The **Awareness** section will describe these climatic factors and show how they are modified by landforms and urban forms found in Calgary.

CLIMATE

Macroclimate of Calgary

Winter in Calgary comes earlier and lasts longer than in any other major city in Canada. On average, the season begins in the third week of October and lasts 188 days, approximately until the third week of April (Klivokiotis & Thomson, 1987). The simple fact that more than half of an average year in Calgary is spent in winter indicates the importance of designing for a winter climate.

The climate of Calgary and most of the prairies is classified as "continental". A continental climate is characterized by strong temperature contrasts between day and night; warm, moist air masses are relatively uncommon. Calgary's high elevation (1050 m downtown) also contributes to the large daily temperature variations.

Additional information on Calgary's weather can be found in Klivokiotis and Thomson (1987), The Climate of Calgary.

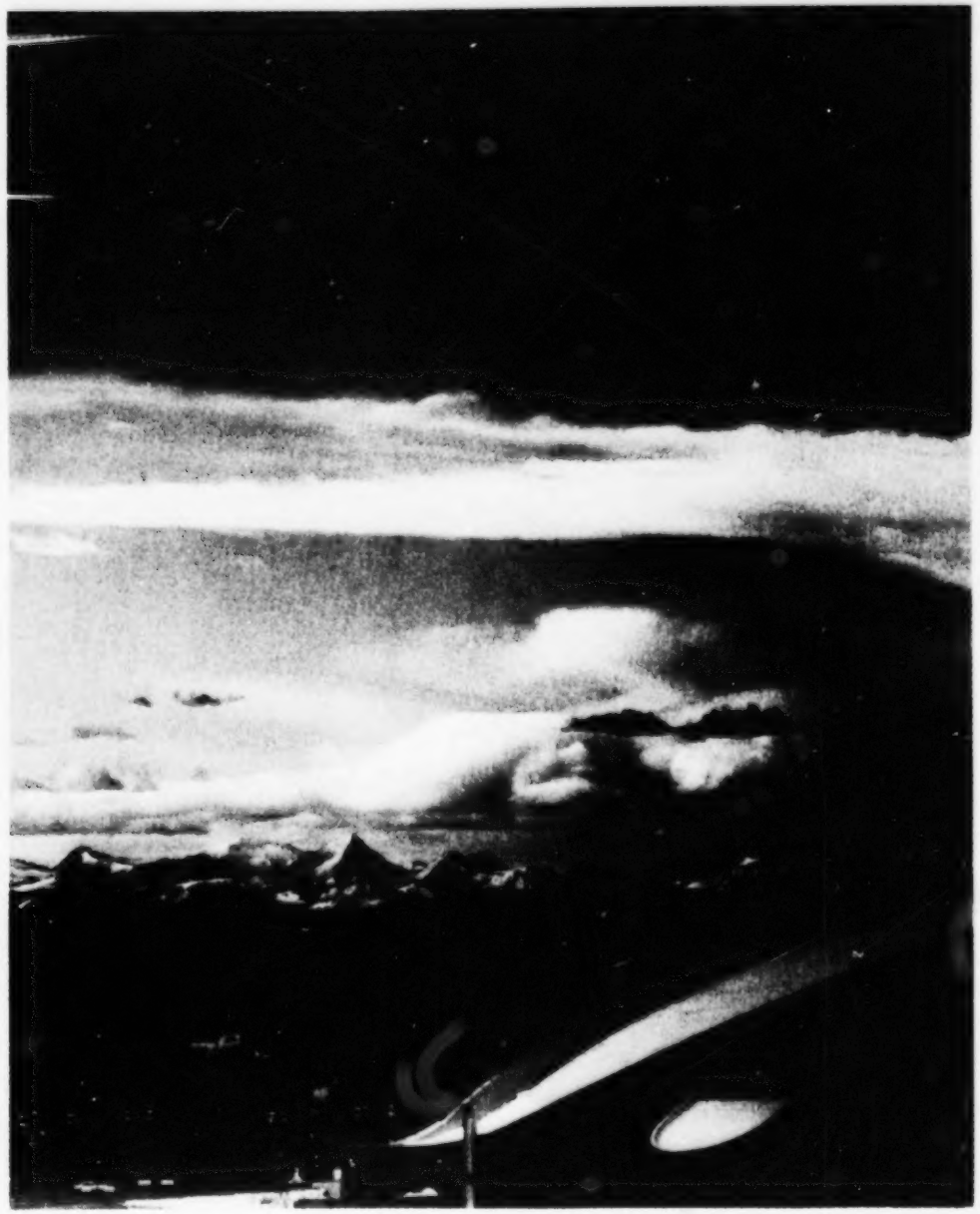
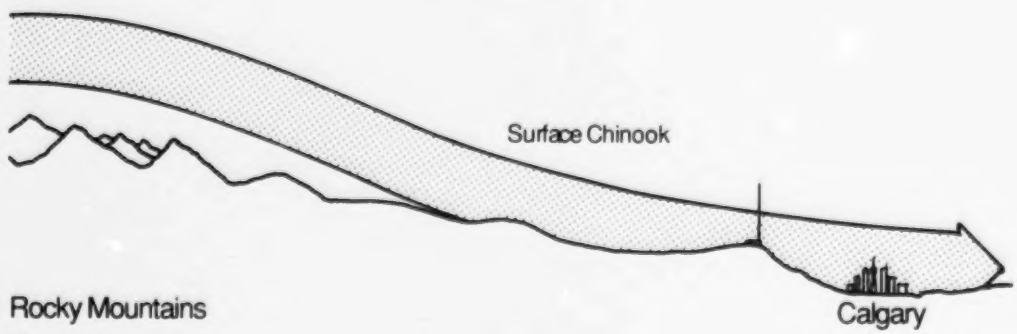


Figure 1.1 A Chinook developing on the western horizon.

Figure 1.1



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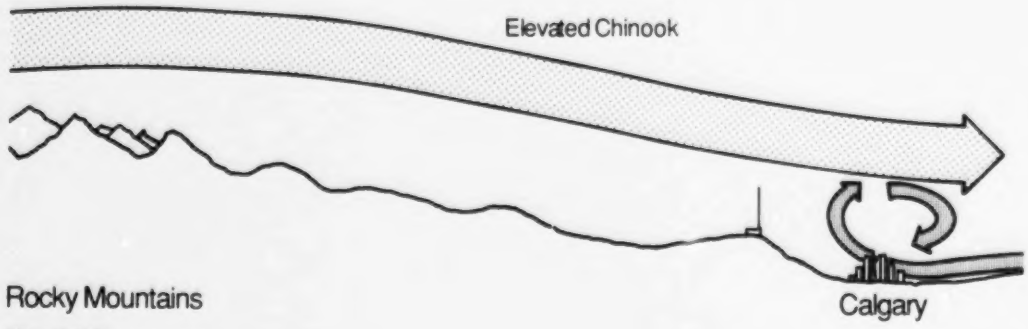

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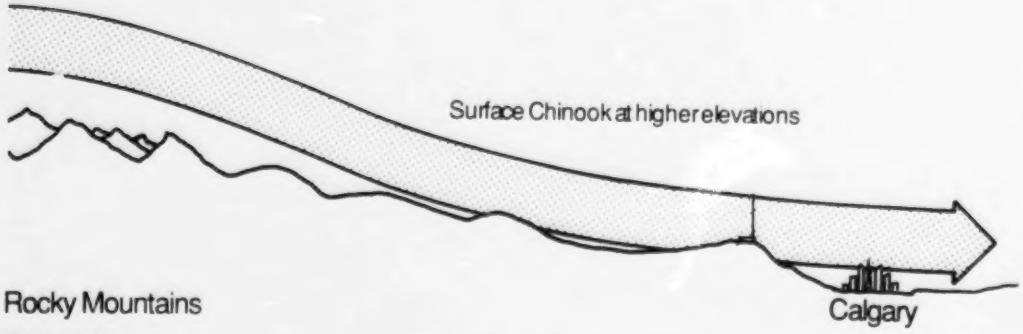


Figure 1.2c

Chinooks

What makes Calgary's winter season truly unique is not the length, but rather the extreme variability. Chinooks are the major weather events that distinguish Calgary's winter from those of other winter cities. Chinooks affect the Calgary region in three ways (**Figure 1.2**):

a Chinook winds that reach the ground surface cause warm, dry, windy conditions throughout the region.

b Elevated Chinook winds trap colder air over the city, resulting in reverse circulation, easterly winds and temperature inversions.

c Elevated Chinook winds may contact areas of higher elevation (e.g., Nose Hill), creating surface Chinook conditions only in these areas.

Calgary receives Chinooks as a direct result of its proximity to the Rocky Mountains. Chinook winds develop from warm Pacific air masses rising over the western Cordilleran mountains. As the air rises, the resulting decrease in air pressure releases precipitation and has the effect of warming and drying out the air mass. The arrival of a surface Chinook is characterized by a sharp rise in temperature, a decrease in the relative humidity and the presence of strong westerly winds (Klivokiotis & Thomson, 1987).

Figure 1.2 Different wind pattern during Chinooks: a) Surface Chinook, bringing warm, dry air and windy conditions, b) Elevated Chinook trapping cold air over the city and creating easterly winds, c) Elevated Chinook contacting areas of higher ground (e.g., Broadcast Hill).

Occasionally an elevated Chinook will precede a surface Chinook. Between 1951 and 1980 Calgary averaged nearly four surface Chinooks per year. The greatest number of Chinooks was eight in 1965, which lasted a total of 36 days. The winter of 1958 is the only one, to date, in which a Chinook was not experienced. A Chinook can last for less than a day or for as long as two weeks. The frequency of Chinooks reported here may seem low; however, Pacific air masses can bring conditions similar to those experienced during surface Chinooks.

Common Weather Conditions

Winter weather systems affecting Calgary are often simultaneously comprised of pleasant and unpleasant extremes. Three combinations weather of conditions are common:

1 During Chinooks, unseasonably warm temperatures are accompanied by strong winds.

2 Arctic air masses bring cold north winds and sunny sky conditions.

3 Air masses from the south deliver Calgary's largest snowfalls, light winds and average to above-average temperatures.

When considering climate with respect to winter design, the extreme weather conditions (mild and severe) and the normal or average conditions are important. People spend less time outside during severe weather periods and time spent outside is generally only to get from one indoor space to another. People spend more time outside during exceptionally mild and pleasant weather conditions, when moving from place to place, during spare time and for recreation. Information on the effects of winter weather on people in Calgary is discussed in Lee and Kirby (1988), Calgary in Winter.

Typical or average weather conditions occur during transitional periods between weather events when the air masses are weakly developed or while under the influence of Pacific air masses in the absence of Chinook conditions. Designing for severe weather conditions will usually mitigate the problems associated with average conditions. However, there may be situations where designing for severe conditions is not feasible (economically or otherwise) and designing for average weather conditions may be necessary. A table of mean and extreme winter conditions is provided in the Appendices.

Temperature

Large temperature ranges between night-time lows and day-time highs are common in Calgary. The mean daily temperature range in Calgary is 12 C°, while in Vancouver and Toronto it is less than 7 C°. Chinook conditions also cause rapid day-to-day temperature variations. One winter day in 1988 the temperature reached a morning high +14 °C, but by early afternoon the temperature dropped to -24 °C as Chinook conditions were replaced by an Arctic air mass.

There is a large difference between the extreme minimum and maximum temperatures for the winter months (**Figure 1.3**). Mean (and extreme) temperatures are lowest in January (mean -11° C) and increase fairly steadily towards early and late winter months (mean -3° C). Temperatures tend to be highest during Chinooks, lowest while under the influence of Arctic air masses and moderate while under the influence of westerly and southerly air masses.

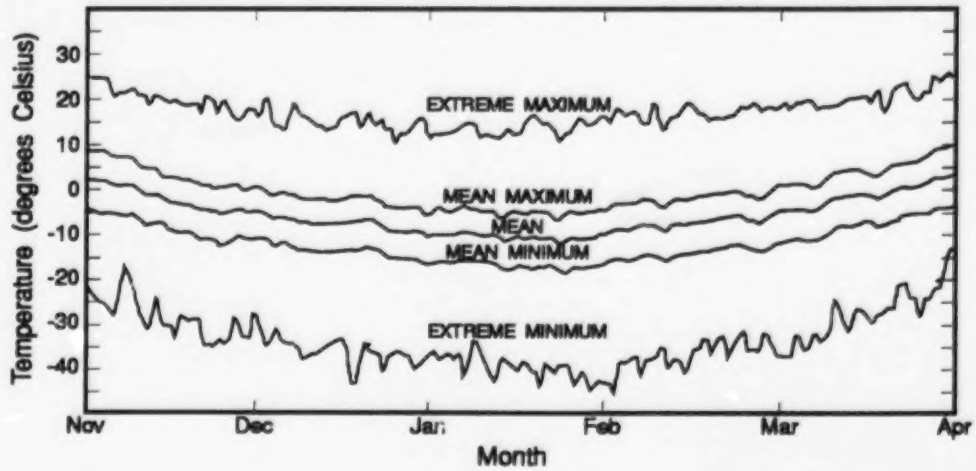
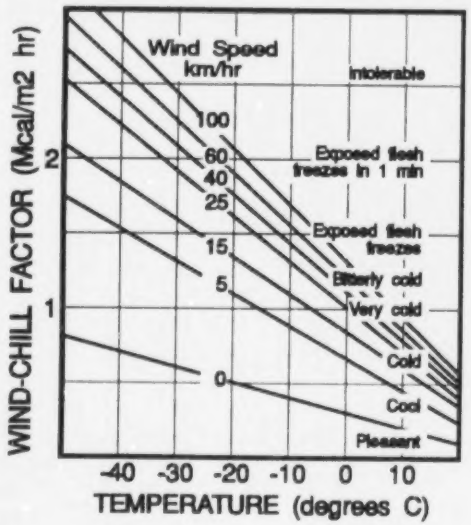


Figure 1.3 Mean and extreme temperatures for winter months in Calgary (Source: Klivokiotis & Thomson, 1987).

Figure 1.3



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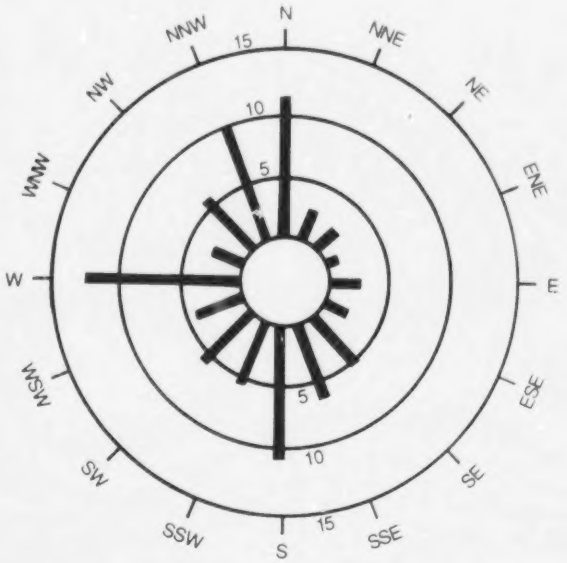


Figure 1.5

Wind

Brisk winds are a normal part of Calgary's winter. Winds exceeding 50 km/hr occur on an average of 40 days each winter. Sustained winds occasionally reach 90 km/hr during Chinook conditions. High winds are not only unpleasant but can also be dangerous, particularly if they come in strong gusts.

There are three dominant wind directions-north, west and south (**Figure 1.5**)-relating to the type of weather system affecting the Calgary region. Westerly winds are the strongest and are commonly associated with Chinook conditions. Southerly winds are lighter and are associated with southerly air masses. Northerly winds are moderate and are associated with Arctic air masses.

	FREQ%	SPEED (km/hr)
N	11	20
NNE	3	17
NE	3	13
ENE	1	12
E	3	12
ESE	2	14
SE	6	14
SSE	6	15
S	10	13
SSW	5	12
SW	6	11
WSW	4	20
W	12	28
WNW	3	22
NW	6	16
NNW	10	21
CALM	9	

The wind-chill factor is a measure of the rate at which exposed flesh will freeze due to the combined effect of air temperature and wind. Severe wind-chills are most common in December and January. During these months the wind-chill creates conditions unpleasant for outdoor activities even during sunny days for an average of 27 days (Klivokiotis & Thomson, 1987). Severe wind-chills are most commonly associated with Arctic air masses and the accompanying northerly winds.

The relationship between wind speed and the wind-chill factor is illustrated in **Figure 1.4**. The largest increase in wind-chill occurs at low wind speeds. At -11 °C (mean temperature for January), an increase in wind speed from near 0 to 15 km/hr changes a cool day to a bitterly cold day, illustrating the importance of wind as a winter design consideration.

Figure 1.4 Relationship of wind-chill factor to temperature. The relative comfort level of different wind factors is indicated (Source: Lee & Kirby, 1988).

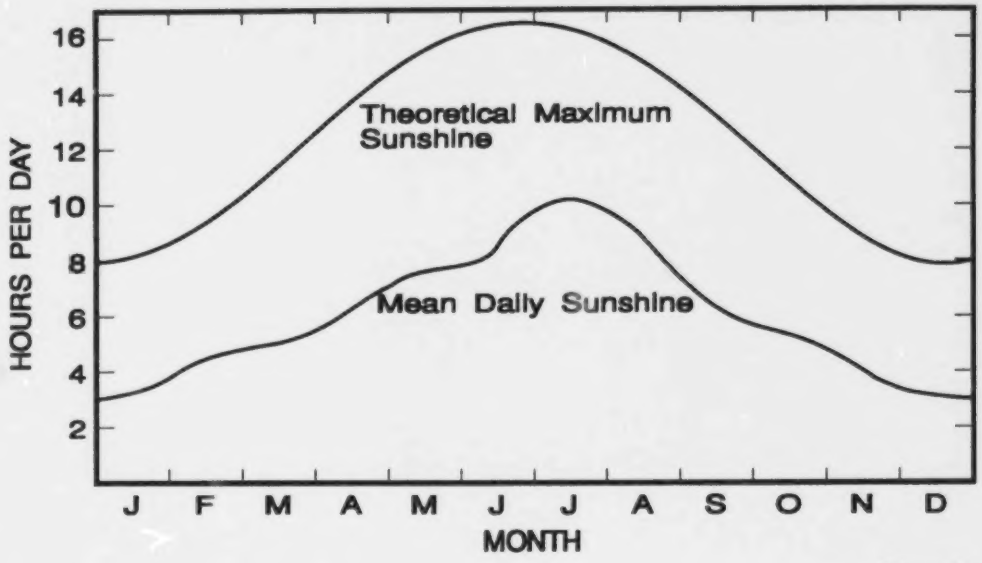
Figure 1.5 Wind direction rose diagram, and wind speed and frequency table (Source: Klivokiotis & Thomson, 1987).

Sun

Bright sunshine is abundant in Calgary during winter, occurring during 50 percent of daylight hours. However, Calgary's location at a latitude of 51° N, means winter daylight lasts only from 8 to 11 hours each day (**Figure 1.6**). Winter sun angles are also low, with a late December maximum solar angle of 16° compared to 62° in June (**Figure 1.7**).

Exposure to the sun's warming rays will result in varying degrees of heat retention or absorption, depending on surface conditions. Absorbed solar energy is then radiated back into the atmosphere and can increase local temperatures, especially in areas unaffected by wind. The orientation of a surface will determine the intensity and duration of exposure to solar radiation, as well as exposure to local or prevailing winds. The absorption of direct solar radiation by pedestrians can, in the absence of wind, significantly increase perceived temperatures (Oke, 1978). Reducing wind speed is critical to effectively utilizing solar radiation.

Southerly slopes receive the highest levels of direct solar radiation. Western and eastern exposures receive moderate amounts of solar radiation while northern aspects receive the least. Solar radiation increases substantially with increasing slope only for southern exposures (**Figure 1.8**).



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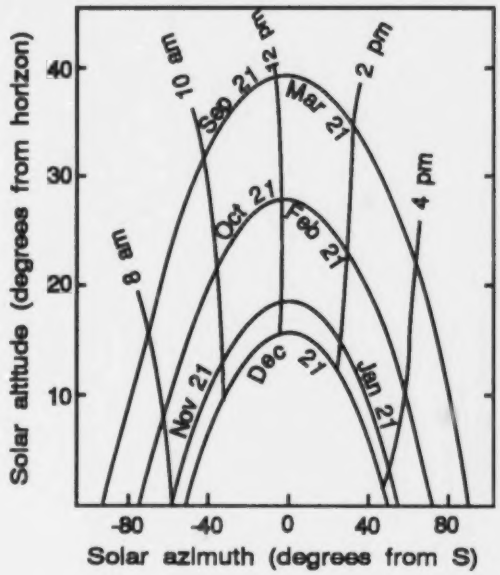

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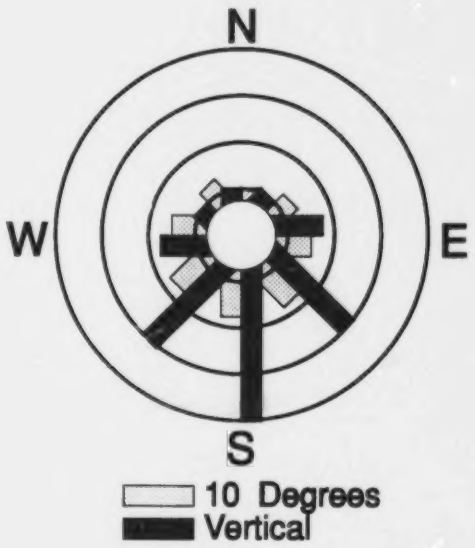


Figure 1.8

Figure 1.6 Mean and maximum daily sunlight hours in Calgary (Source: Klivokiotis & Thomson, 1987).

Figure 1.7 Sun elevation and azimuth (degrees from south) for winter months in Calgary.

Figure 1.8 Relative strength of January mean daily incident solar radiation at different slope orientations for a vertical surface and a 10° (from horizontal) slope.

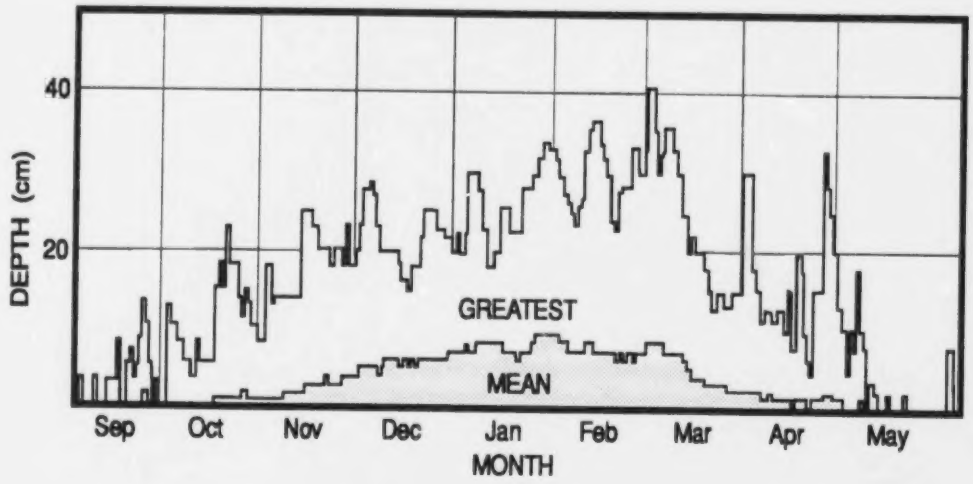


Figure 1.9

Precipitation

Calgary receives an average of 150 cm of snow annually of which 130 cm falls during the winter. This compares to annual snowfalls of 140 cm in Toronto, 140 cm in Edmonton and 240 cm in Montreal. While snow fall tends to be fairly evenly distributed throughout the winter months in Calgary, the reliability of snow cover is variable. Periodic Chinooks cause rapid melting and daily temperature variations that create a fairly severe freeze-thaw cycle during the winter. "Reliable snow cover" (2.5 cm of snow lasting at least 7 days) has historically lasted for between 27 and 182 days annually, with an average of 116 days. Average depths of snow on the ground are quite low in Calgary (**Figure 1.9**), with a maximum average depth of slightly less than 10 cm in January.

Figure 1.10

Figure 1.9 Mean and maximum depth of snow on the ground at the Calgary International Airport (Source: Klivokiotis & Thomson, 1987).

Figure 1.10 An example of Residential Development in the Bow River Valley. Note the steep valleys sides which reduce the impact of northerly winds and are subject to high levels of solar radiation.

Mesoclimate of Calgary

The topography of Calgary influences local air circulation patterns and can have a significant influence on wind patterns and temperatures. As described in the earlier discussion of **Sun**, exposure to the sun is determined by slope orientation and angle. In order to provide an understanding of the variations that exist in Calgary's landscape, the city has been divided into four different landform units, each having a characteristic topography (**Figure 1.11**). Most significant changes in relief in Calgary are located at landform boundaries. Climatic variations in each of the landform zones in Calgary are described below.

Calgary's Evolving Landscape

Erosion by rivers flowing eastward out of the Rocky Mountains has shaped the landscape of Calgary for the past 150 million years and has formed the flat-bottomed steep-sided River Valleys common throughout Alberta. This evolving landscape has been significantly modified in the past one million years by a series of glaciations. The most recent glaciation, between 14,000 and 18,000 years ago, has had the most profound effect on the landscape. The evolution of Calgary's landscape is discussed in more detail in Jackson (1987), Geology of the Calgary Area.

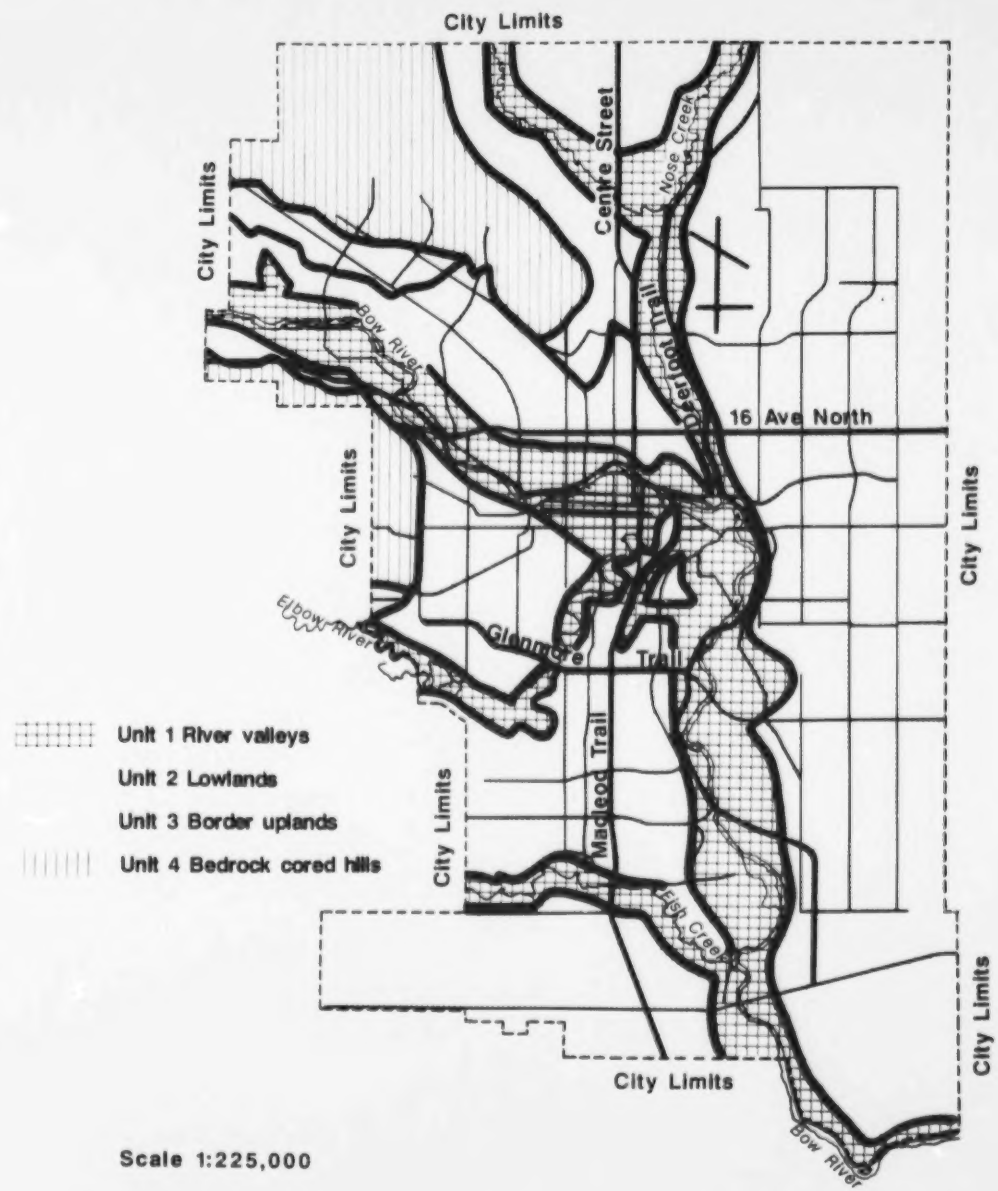


Figure 1.11 Landform map of Calgary.

Figure 1.11

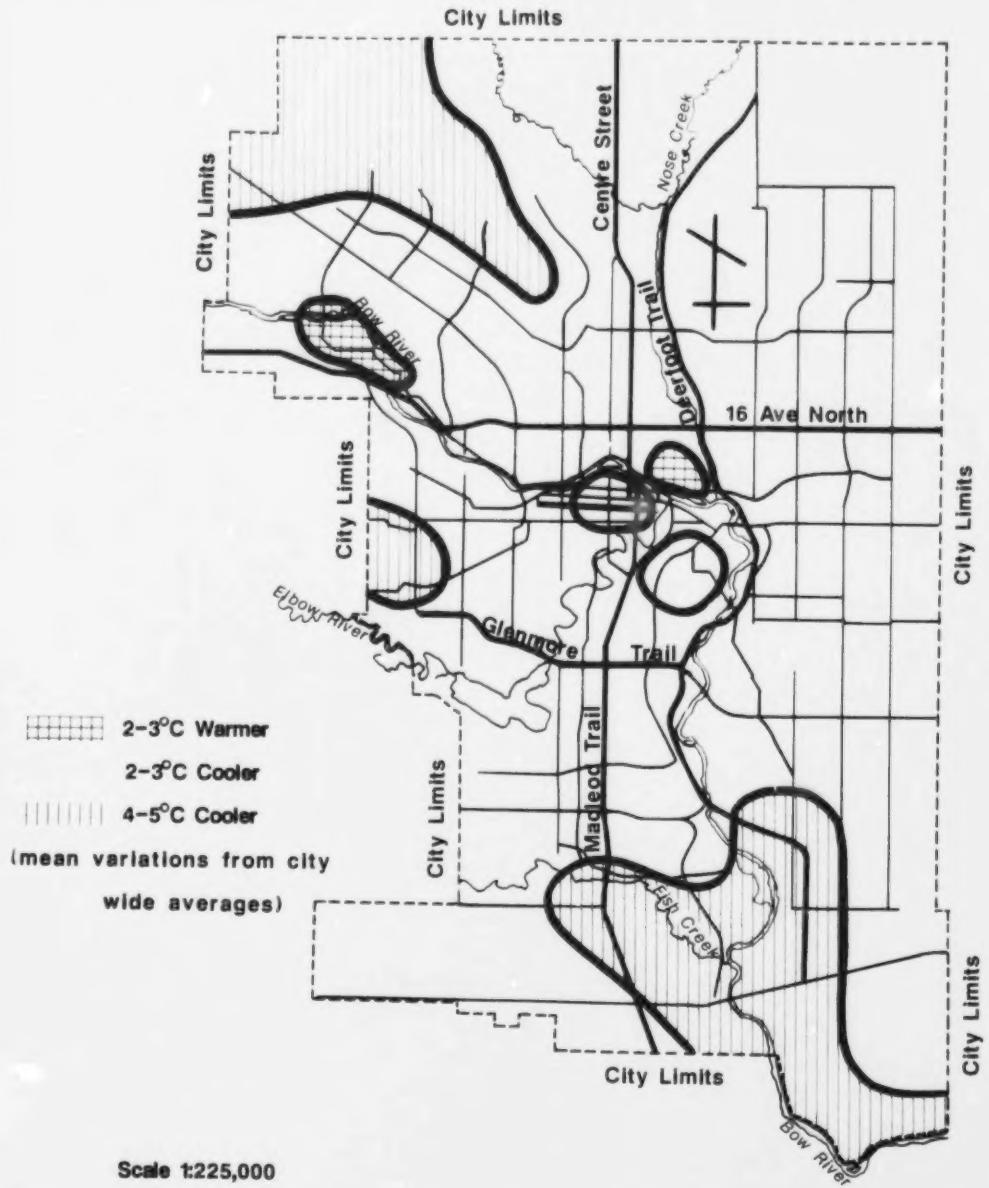


Figure 1.12

River Valleys (Unit 1)

Valleys of the Bow River and its tributaries form Landform Unit 1 (**Figure 1.11**). River Valley bottoms tend to be relatively flat and valley sides steep (10 to 30°). Valley bottoms form the lowest elevations in the Calgary area. River Valleys are primarily oriented east-west and north-south, hence the slopes tend to have uniform orientations.

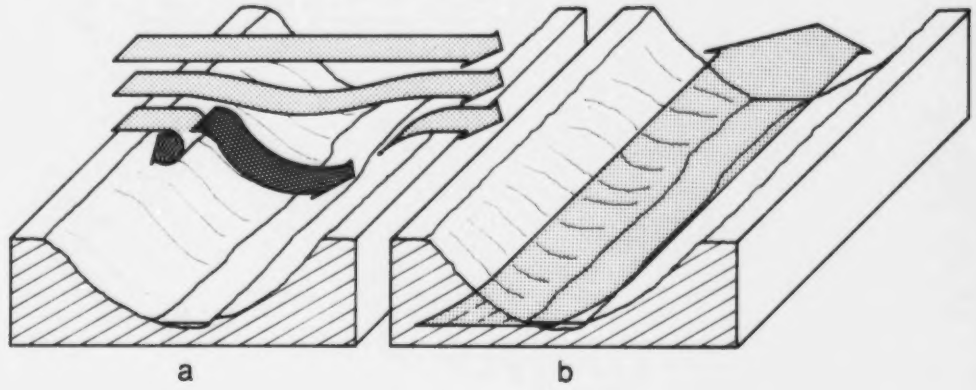
Two areas within the River Valleys, corresponding to the communities of Bridgeland and Bowness, are subject to a phenomenon referred to as cold air drainage (Nkendirim et al., 1977). Cold air from surrounding areas of higher elevation is denser than surrounding air and tends to drain into and collect in these lower areas. This results in temperatures in Bridgeland and Bowness which average 2 to 3 C° colder than mean city temperatures (**Figure 1.12**).

The orientation of a River Valley will provide shelter from some winds while funnelling and redirecting others (see **Figure 1.13**). South- and east-facing valley sides and nearby valley bottoms are sheltered from northern and western winds respectively. In general, the steeper the slope and deeper the valley, the wider is the area of sheltering or eddying at the base of the slope (Oke, 1978). River Valleys contain the highest density of tree growth in Calgary and trees are effective at reducing wind speeds by sheltering and filtration.

Figure 1.12 Temperature zone map of Calgary (Modified after Nkendirim et al., 1977).

Sun exposure for River Valleys relates to the orientation of valley sides as described in the earlier discussion of **Sun**. Some typical shadow diagrams for River Valley cross-sections are illustrated in **Figure 1.14**.

The swift flow of the Bow River and its tributaries prevents them from completely freezing over, particularly stretches of riffles and rapids. During cold periods, especially during temperature inversions, condensation of water evaporated from open stretches of the rivers can accumulate and cause serious fog problems.



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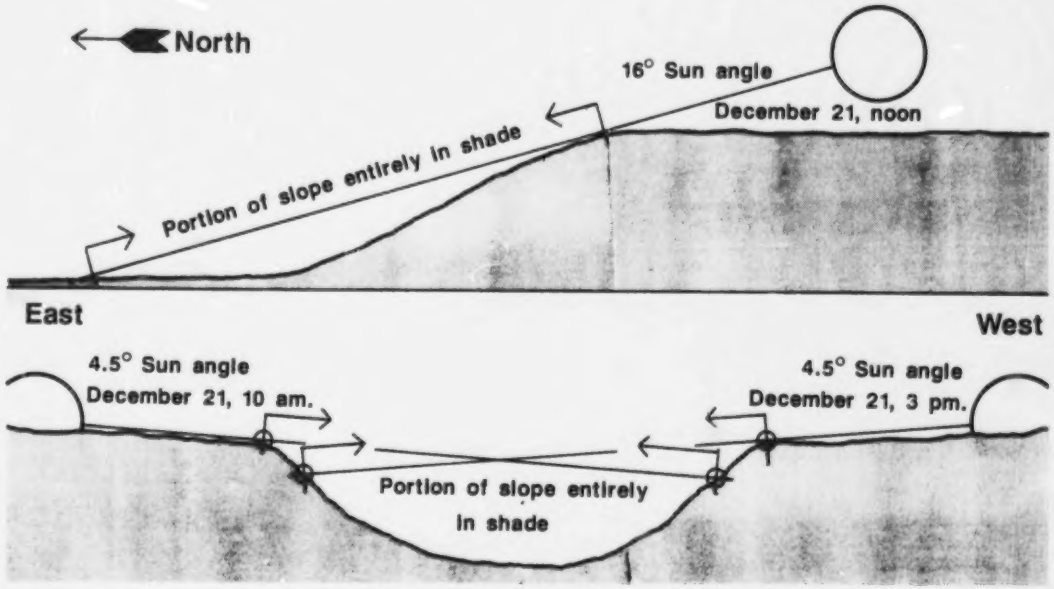


Figure 1.14

Figure 1.13 River Valleys which have predominantly north-south and east-west orientations will a) be sheltered from or b) channel northerly or westerly winds depending on orientation (e.g., north-south valley will be sheltered from westerly winds and channel northerly winds).

Figure 1.14 Typical shadow profiles for late December in Calgary for a steep north-facing valley slope and a moderately sloping west-facing valley slope.

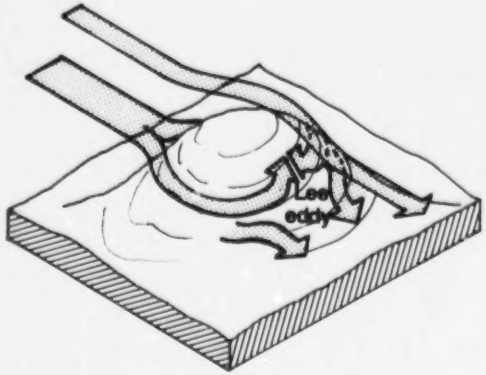


Figure 1.15

Lowland Areas (Unit 2)

Bordering the River Valleys are Lowland areas in which much of the central and southern portions of the city are located (**Figure 1.11**). West of Deerfoot Trail, most of the Lowland areas were covered by a deep lake during the last glacial period. This resulted in the deposition of silts and clays which are responsible for the flat topography found throughout much of the area (**Figure 1.16**). East of Deerfoot Trail (Highway 2), the topography is more rolling due to debris deposited by retreating glaciers.

Areas of higher elevation bordering Lowland areas have the strongest effect on the climate of Lowland areas. Nose Hill moderates north and north-westerly winds in Lowland areas north of the Bow River while Broadcast Hill moderates westerly and northwesterly winds in Lowland areas south and west of the Bow River (Nkendirim et al., 1977). The moderating effect results from the separation of the wind as it passes over and around the hills (**Figure 1.15**). In the late afternoon, Lowland areas directly east and north of Broadcast Hill are in shadow.

Border Uplands (Unit 3)

Border Uplands (Landform Unit 3) occur on the flanks of Bedrock-Cored Hills (Landform Unit 4) (**Figure 1.11**). The Border Uplands have moderate slopes (5 to 14°), undulating topography and fairly uniform aspects (**Figure 1.17**).

There are four distinct areas of Border Uplands: two south-facing areas south of Nose and Broadcast Hills, an east-facing area east of Nose Hill and a north-facing area north of Broadcast Hill. As a result of their relatively uniform aspect, each of these areas also have a relatively uniform sun exposure.

Border Uplands and Bedrock-Cored Hills are commonly cooler than Lowland areas and most areas of the River Valleys. The Bedrock-Cored Hills moderate winds from an upwind direction due to the eddying effect as the wind breaks over and around the hills.

Figure 1.16

Figure 1.15 Generalized wind circulation around and over Bedrock-Cored Hills (Source: Oke, 1978).

Figure 1.16 An example of the flat topography characteristic of Lowland areas. There is very little topographic influence on climate in Lowland areas.

Bedrock-Cored Hills (Unit 4)

Two Bedrock-Cored Hills, Nose Hill and Broadcast Hill, form Landform Unit 4 (**Figure 1.11**). They have moderate to steep slopes (10 to 20°), undulating tops and form the highest elevations in Calgary (**Figure 1.18**).

Bedrock-Cored Hills experience the highest winds in the Calgary region, particularly on west and north slopes and on plateaus. South and east aspects are sheltered from northerly and westerly winds respectively. Aspect of slopes at the margins of Bedrock-Cored Hills determines sun exposure.

Figure 1.17

Figure 1.18

Figure 1.17 An example of a south-facing Border Uplands area. This area is sheltered from northerly winds and has good sun exposure.

Figure 1.18 The community of Edgemont is perched on Nose Hill, an example of a Bedrock-Cored Hill. As a price to pay for a great view, Edgemont is subject to the strongest winds in the city.

Summary

The overall climate (macroclimate) of Calgary was described, beginning with the common weather conditions experienced and concluding with a discussion of four climate factors: temperature, wind, sun and precipitation. Local variations in climate (mesoclimate) were explained by dividing Calgary into four areas of distinct topography (Landform Units) and discussing climatic variations within each of the Landform Units. It is apparent that wind and sun exposure are the factors most amenable to human intervention.

At the mesoclimate scale, we can begin to understand how buildings will interact with the climate. How climate and landform relate to the built environment will be covered in the following chapter on Calgary's **Urban Form**.

URBAN FORM

The development of Calgary's urban form has been influenced by a variety of factors including the physical landscape, landmark developments, city planning and zoning by-laws. The first and most significant development was the placement of the CPR mainline in the 1880's. It is between this rail line and a north-south bend in the Bow River that Calgary's historic core and current business section is compressed. In the early days, the city adopted a north-south and east-west grid-iron street pattern. The "City Beautiful Movement" modified the existing grid pattern to create attractive street systems (e.g., Mount Royal). In recent years development has been primarily on a cellular street form.

Residential development in Calgary has tended to follow the River Valleys, first to the south and west along the Elbow River and more recently along the Bow River to the northwest and southeast. Glenmore Reservoir, Fish Creek Provincial Park and the Sarcee Indian Reserve have limited urban development.

Calgary adopted its first zoning by-laws in 1934. The land zoning pattern has resulted in areas of the city having distinct functional characteristics. The downtown business section, south-east industrial suburb and various residential districts are a direct result of this approach (**Figure 1.19**).

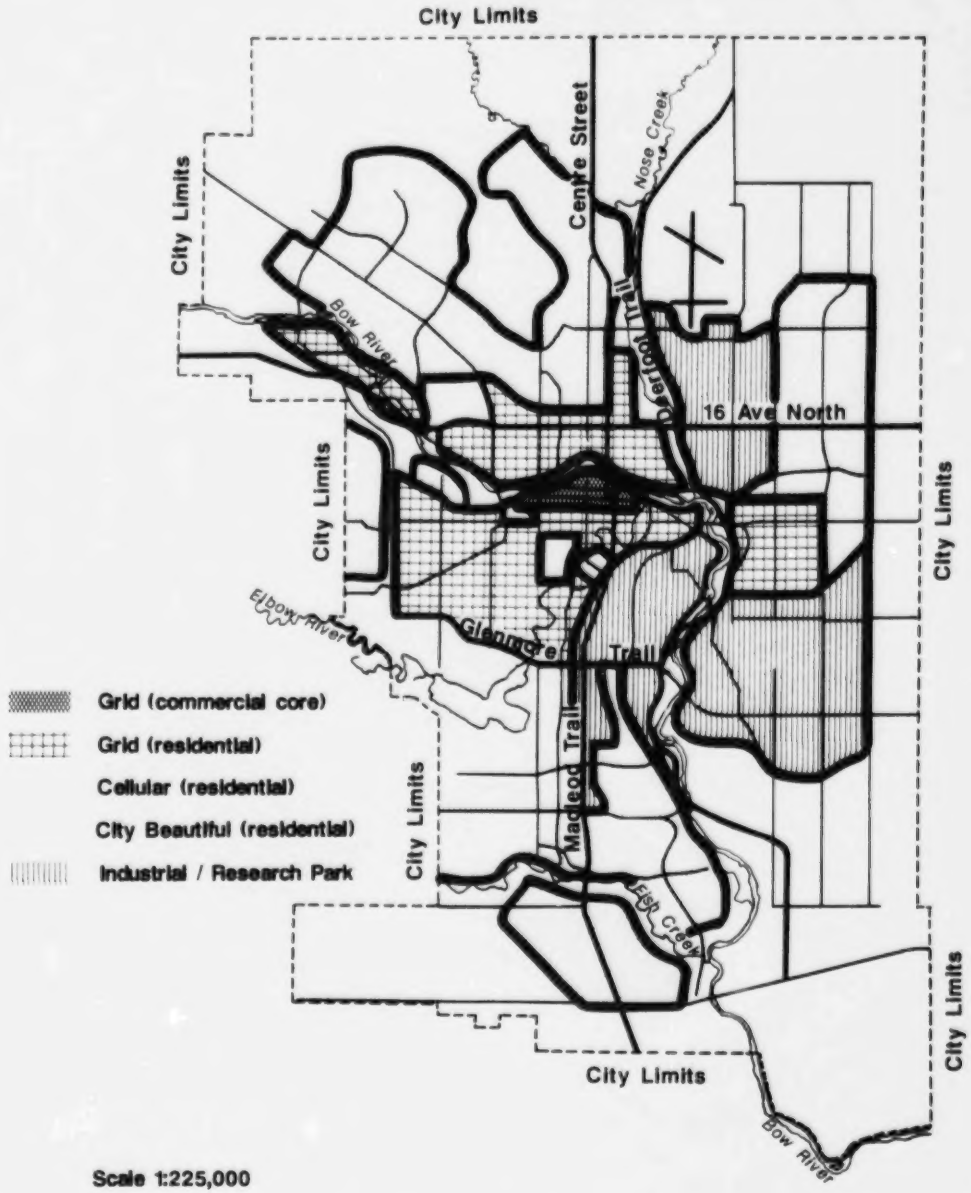


Figure 1.19

Figure 1.19 Urban Form map of Calgary.

Figure-Ground Relationships

Figure-ground relationships are important in understanding the basic types of urban form in the city. Two elements are made evident by a figure-ground drawing. One is the placement of buildings (figure), shown in black and the other is the extent of open space (ground), shown in white (see **Figures 1.20 through 1.24**). The separation of urban form into buildings and open space is an important distinction to make when studying how urban forms affect climate. The effect of building height is not represented in a figure-ground, but is also an important consideration.

The urban form as a whole is a modifier of climate. Buildings are solid blocks placed on land which modify the climate of the surrounding open spaces in terms of temperature, wind, sun exposure and snow accumulation. Any place where no buildings exist, the ground can take a variety of forms, but is essentially open to the effects of climate. Each of the figure (buildings) and ground forms (open space) are modifiers of climate and it is the interrelationship of these modifiers which affects the climate of any given area. Five general types of urban form exist in Calgary:

1 The downtown core consisting of high density commercial development in the form of high-rise towers placed on a north-south and east-west grid street pattern and punctuated by occasional plazas, squares and trees. The downtown core is located within the River Valleys (e.g., **Figure 1.20**).

2 Industrial areas of low- and medium-density development placed on a grid-street pattern in River Valleys and adjacent Lowland areas in the southeast part of the city, with extensive open space and limited vegetation (e.g., **Figure 1.21**).

3 Inner city residential areas of low- and medium-density placed on a grid street pattern in River Valleys and Lowland areas; accented by occasional commercial areas, institutional buildings and established vegetation (e.g., **Figure 1.22**).

4 "City Beautiful" residential areas set on a modified grid-street pattern, with extensive open space and vegetation (e.g., **Figure 1.23**).

5 Residential areas of low- and some medium-density development placed on a cellular street pattern oriented to topography and major roadway edges, punctuated with extensive open space and vegetation. They are located in all landform units and are the only urban form found on Bedrock-Cored Hills and adjacent Border Uplands in Calgary (e.g., **Figure 1.24**).

Climatic Effects

The grid-street patterns developed in River Valleys and Lowlands channel northerly and westerly winds whereas the cellular street patterns are more effective at moderating wind velocities and preventing extensive channelling. However, in many cases the landform will play a greater role than street form in determining wind exposure. For example, cellular residential subdivisions such as Beddington, Edgemont (see **Figure 1.19**) and Silver Springs are exposed to higher wind speeds and greater amounts of drifting snow than other parts of the city because they are located on Bedrock-Cored Hills and Border Uplands.

The amount of vegetation in the extensive open spaces found in most residential areas is another factor affecting wind. Newer communities have fewer mature trees, conifers in particular, to intercept wind than do older established communities. Vegetation will also be more susceptible to winter damage in areas with higher winds and cooler temperatures (i.e., Bedrock-Cored Hills and Border Uplands).

The extreme roughness of the downtown core, created by the high concentration of tall buildings, breaks up laminar (parallel) air flow and results in more turbulent wind conditions. This is further exacerbated by the grid-street system in this area. In general, wind velocities are moderated in high-density areas compared to lower density areas, however peak gusts are higher (Flynn, 1981). At the other end of the spectrum, industrial areas with low building densities and limited vegetation have little influence on wind patterns.

Figure 1.20 Figure-ground relationship of Calgary's downtown core. Grid pattern channels northerly and westerly winds, while high building density limits light penetration.

Figure 1.21 Figure-ground relationship of industrial and research park areas. Low building density and limited vegetation allows excellent light and wind penetration.

Figure 1.22 Figure-ground relationship of a medium-density residential area. Grid pattern channels north and west winds and makes it difficult to design for effective sun penetration.

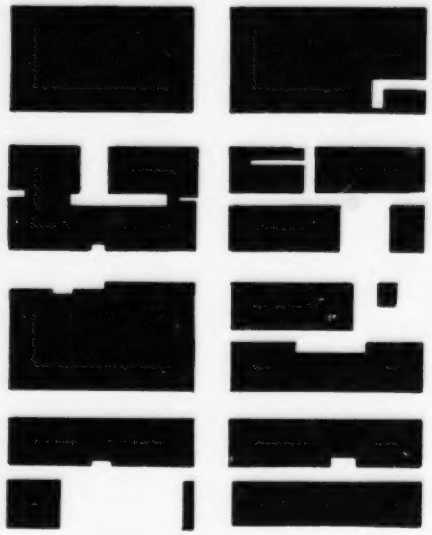


Figure 1.20

Figure 1.21

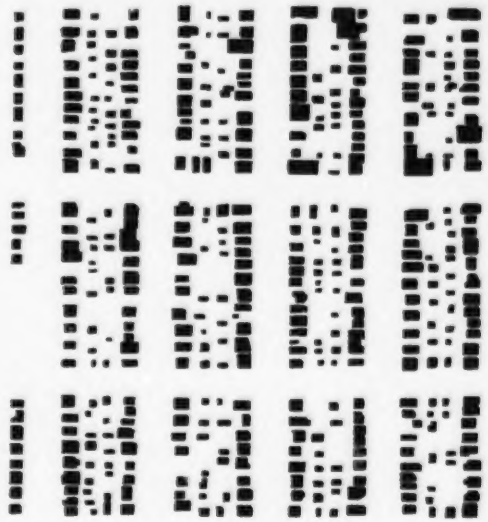


Figure 1.22

Figure 1.23

Figure 1.23 Figure-ground relationship of a "City Beautiful" residential area. Roadways can be located to accommodate topography, and to allow for effective sun penetration.

Figure 1.24 Figure-ground relationship of a cellular street pattern. Allows the flexibility to accommodate topography, allows for sun penetration, and provides the best shelter from the wind. However, these considerations must be part of the street design for the potential advantages to be realized.

Figure 1.24

The temperature inversions and reverse wind circulation created by elevated Chinook conditions can create air quality problems in Calgary (**Figure 1.25**). The problem occurs year round but is particularly severe during the winter. An elevated Chinook creates a temperature inversion over Calgary resulting in reverse air circulation, easterly winds and reduced atmospheric mixing. Easterly winds carrying higher than normal pollutant levels from industrial areas located in the eastern part of the city, combined with reduced atmospheric mixing, create conditions conducive to a rapid decline in air quality, particularly in River Valleys and surrounding Lowland areas.

A "heat island" is created by the extensive concentration of buildings in the downtown core which radiate heat to the outside and to the ground. This results in average temperatures that are significantly higher (2 to 3 ^{o}C) than in surrounding areas. A similar heat island exists over the Ogden industrial area, but is due to the high rate of heat radiation from buildings rather than building density.

The concentration of tall buildings in the downtown core severely limits sun penetration during the winter. As a result, many open spaces between buildings are almost always in shadow. Snow accumulation in these heavily shadowed areas resists melting during mild weather and can easily become iced over when temperatures fall. Similar situations occur in residential areas where the arrangement of streets and buildings prevents the sun from moderating the street microclimate when sun angles are low.

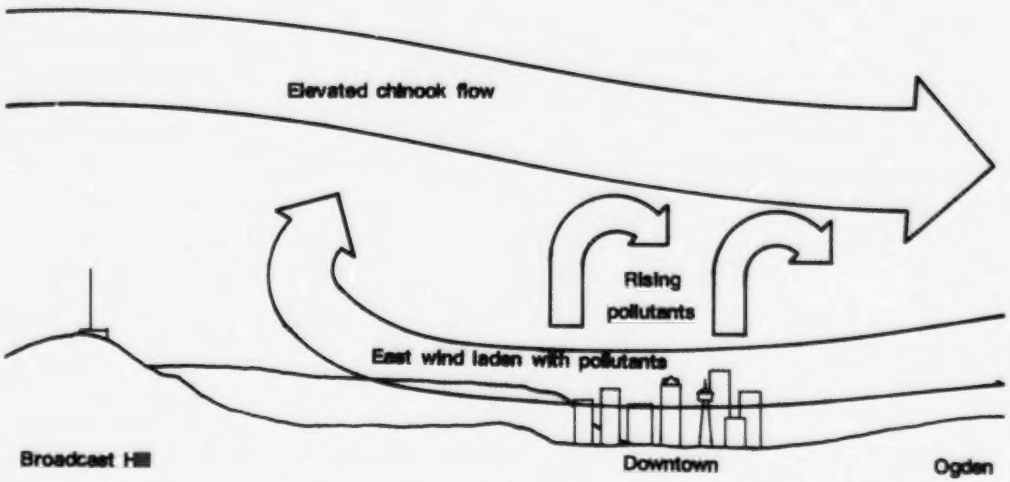


Figure 1.25

Summary

Calgary is a city that experiences the severity of weather conditions that a winter season brings. However, it is also a city that possesses a characteristic variability in climate that periodically makes it a pleasant place to live and work. This is one of the things that gives Calgary a "sense of place" and makes it a unique place in the world.

The **Awareness** section of this manual describes the physical features of Calgary in terms of its climate, landforms and urban form. It establishes which general climatic factors need to be considered when building in Calgary and which are particularly important in different parts of the city.

In order to live more enjoyably and successfully in winter, we must recognize the need for creating a built environment that is appropriate to Calgary's climate. Adaptation has, historically, been what has given towns and cities their own particular regional character. Inherent in this traditional settlement was the response to the land and natural forces and it is one that we must still consider. Today, we possess knowledge and technologies that could make adapting to the climate a much easier task, but it is still knowledge which must be used wisely. The next section of the manual describes some of this information and suggests how it may best be put to use when building in Calgary.

Figure 1.25 Elevated Chinook over Calgary, creating a temperature inversion (i.e., cold air trapped below warm air), easterly winds, and a rapid deterioration in air quality in River Valley and Lowland areas.

BUILDING CONFIGURATION

RELATIONSHIP BETWEEN BUILT FORMS

RELATIONSHIP OF BUILDING TO STREET

BUILDING DETAILS

DESIGN GUIDELINES

INTRODUCTION

The vagueries of winter, common to Calgary, include climatic extremes that act as major impediments to the people who live here. In winter cities it is essential that measures be taken in the design of the built environment to lessen the effects of the worse that winter has to offer and enhance or extend winter's gentler moments.

It is possible to achieve these provisions with microclimatic planning and design of the building site to include features such as protection from wind, orientation for maximum reception of solar radiation, prevention of shadowing by surrounding built and natural elements, the use of heat absorbing and reflecting materials and so on.

The first area of discussion is concerned with **Building Configuration** and how the form of a building, its mass and siting, contribute to either pleasant or adverse microclimatic conditions. The **Relationship Between Built Forms** is then examined. Emphasized in this discussion are the features of collective building forms and their relationship to the landforms of Calgary. The **Relationship of Building to Street** is then presented in terms of how the building's microclimate may be modified and improved by consideration of particular design features such as landscaping. Lastly, particular **Building Details** are examined. Features common to all buildings, such as doors, windows, roofs and entranceways, are viewed from the perspective of making the building more responsive to the winter season.

BUILDING CONFIGURATION

Since 1977, the modelling and testing of new high-rise developments and their effect on street level wind conditions has been required by municipal law (Env. Stds. Sec. 42.1 8a,b). This is achieved primarily through wind-tunnel testing and stems from the pressing need to avoid potentially fatal street-level wind conditions. Strong wind gusts induced by tall buildings can injure and even kill.

For a good part of the winter, wind speeds in Calgary exceed 50 km/hour and can go up to 90 km/hr (see **Awareness**, p. 1-4). The strength and frequency of wind during the winter warrants considerable attention in the design of buildings. These considerations are particularly important when planning the construction of a high-rise building or a building within a concentrated area of existing high-rises.

Horizontal wind speed decreases with proximity to the earth's surface. This phenomenon is caused by a drag effect created by the ground surface and is modified by air moving across the building form. The lower layers of wind are thus slowed down more than those further from the earth's surface.

The drag effect of wind increases with the characteristic 'roughness' of the surface. For example, the uneven city surface exerts a greater drag on wind velocity than does either open country or a body of water (**Figure 2.1**).

While the surface roughness of Calgary's city centre can serve to decrease ambient ground-level winds, wind turbulence, on the other hand, can be greatly increased by ground surface characteristics (i.e., urban form).

Localized effects of building geometry can result in the formation of wind turbulence. Predictions of street level winds can be made if there is an understanding of the characteristics of airflow around buildings. Site-specific predictions of this nature help in understanding the causes of pedestrian discomfort and wind-chill during Calgary's winter months and can lead to preventative or remedial design solutions.

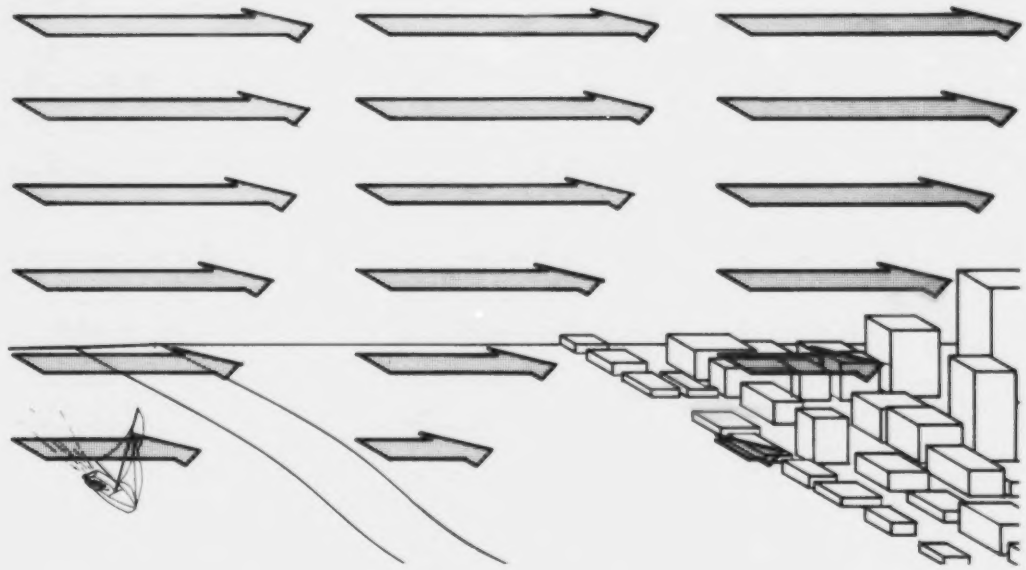


Figure 2.1 Wind conditions over areas of increased surface 'roughness'. Built-up surfaces have lower ambient winds due to surface drag.

Figure 2.1

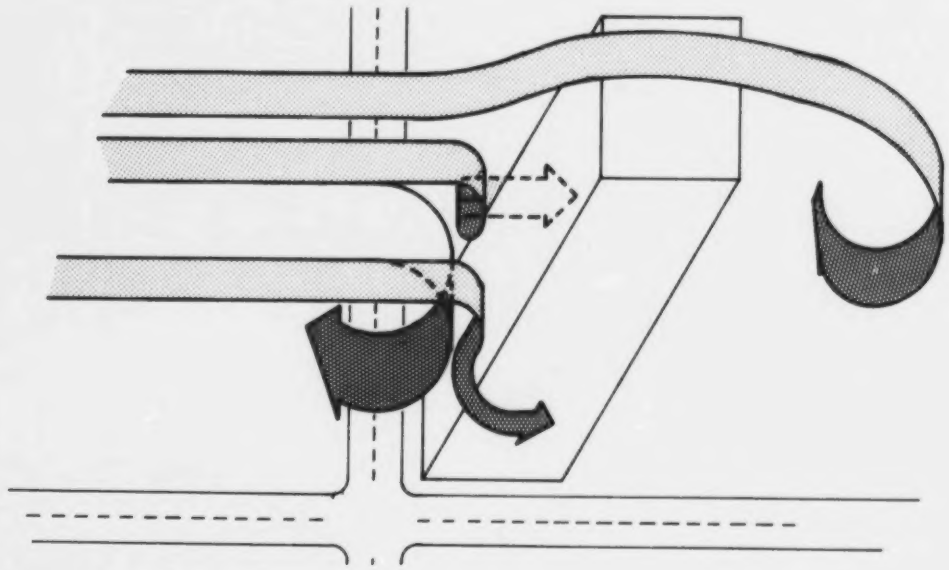


Figure 2.2

When the upper levels of a building are exposed to even moderate winds a pressure difference is created between the building's upper levels, its base and its sides. These pressure differences give rise to potentially violent air turbulence (**Figure 2.2**).

A building induces high-speed ground-level winds if a significant portion of the building is exposed to direct wind flows. It is the direct exposure of a building face to wind, rather than building height alone, which actually causes turbulence problems (**Figure 2.3**). A building of significant height (i.e., 8 stories or more) is regarded to have wind exposure problems if more than the upper half of the building projects above the upstream buildings in any particular wind direction. This is sometimes referred to as the "2H" rule.

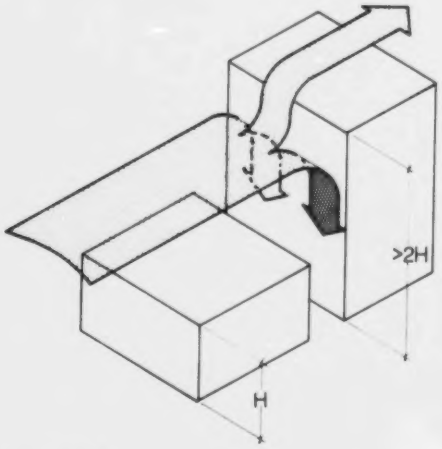


Figure 2.3

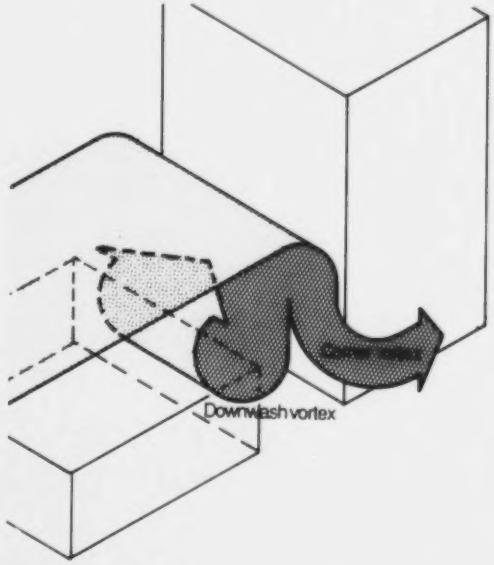


Figure 2.4

Figure 2.2 A building surface exposed to wind creates increased local wind velocities and air turbulence which are potentially hazardous at street level.

Figure 2.3 "2H" rule of wind exposure where more than the upper half of the building is exposed and street level wind problems are induced.

Figure 2.4 Downwash vortex is circular flow created by the presence of a smaller, upwind building.

Because wind speed increases with height, wind pressure on the face of a building also increases as the height of the building increases. The resulting reduced air pressures at lower levels direct the air down, creating a descending flow on the windward side of the building. This phenomenon is called "downwash". When a downwash of air along the face of a building strikes the ground it produces a vortex (**Figure 2.4**). The ends of the vortex are swept around the corners of a building and are referred to as corner vortices. Vortices are responsible for producing turbulent wind conditions at the base of buildings.

The presence of a small building upwind of a larger one can intensify the vortex effect. The upwind building acts as a deflector and serves to increase the pressure differential between the top and bottom of the adjacent high-rise. The space between the buildings functions as a catch to increase the vortex effect at the base of the building (**Figure 2.4**).

The vortex effect can account for as much as a four-fold increase in wind velocity over the ambient level. This would create a sixteen-fold increase in force acting upon a pedestrian at the level of the street, since the force of wind increases by the square of its speed (**Figure 2.5**). A building producing vortex pressures of this magnitude, in conjunction with wind turbulence, has the potential to produce winds with a force strong and sudden enough to blow over a pedestrian. Such an experience has the potential to cause injury and even death.

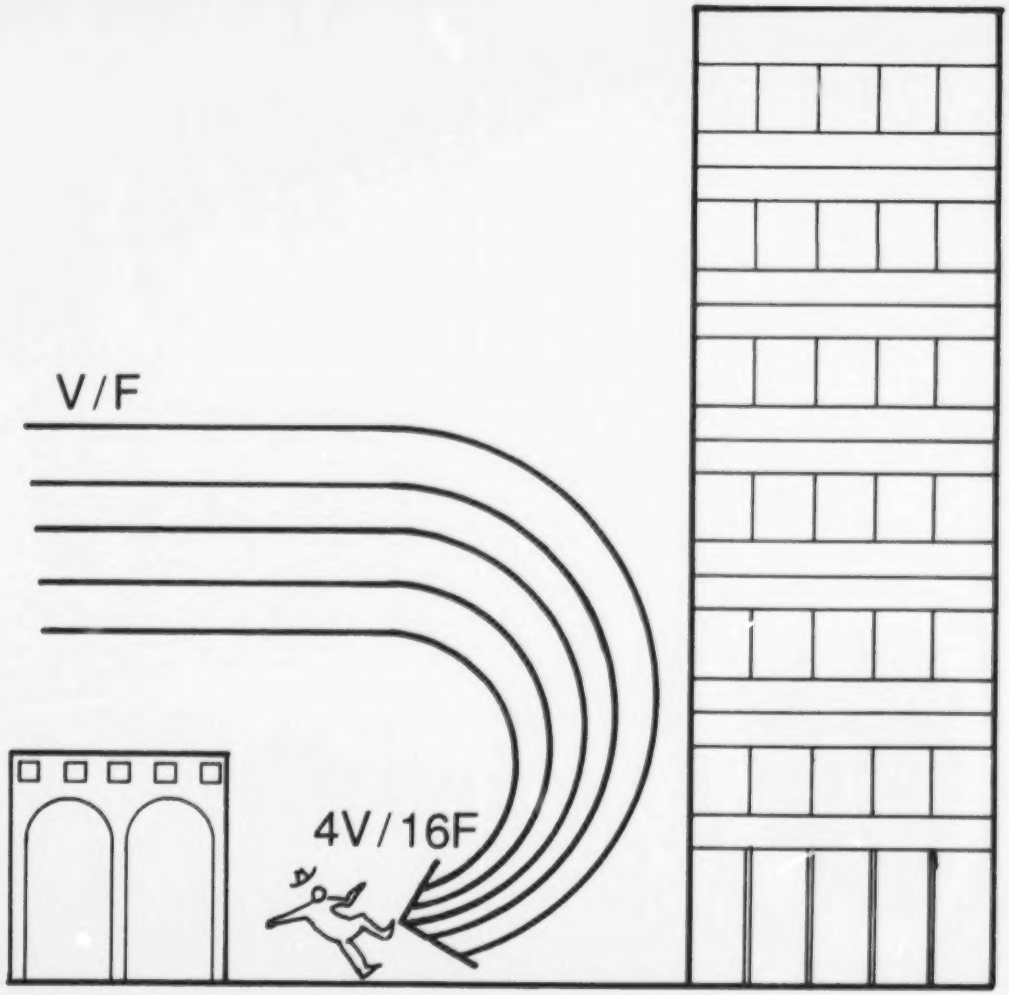


Figure 2.5 A four-fold increase in wind velocity (V) produced by wind vortices creates a 16-fold increase in wind pressure or force (F).

Figure 2.5

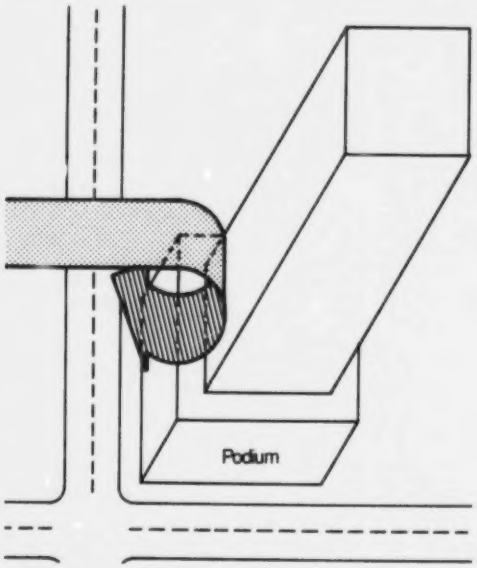


Figure 2.6

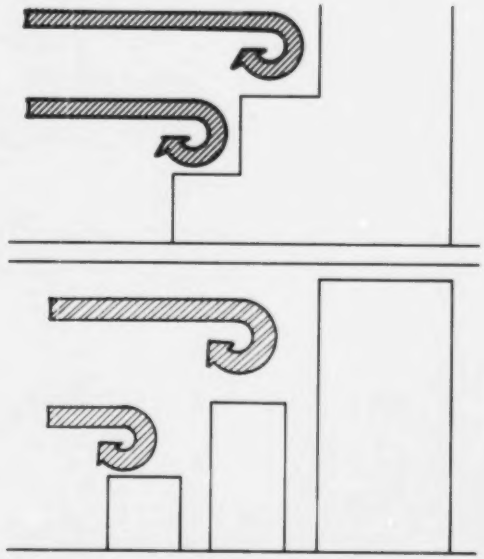


Figure 2.7

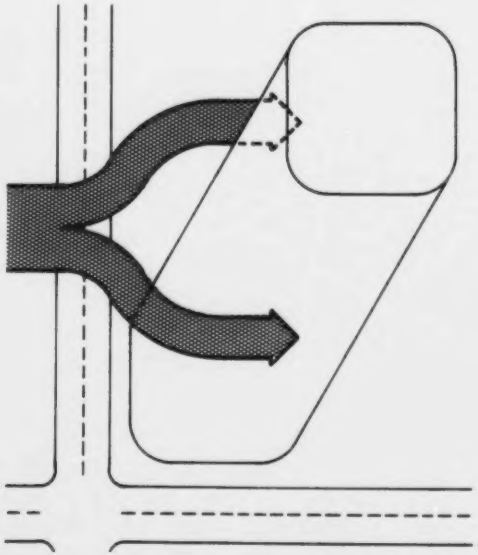


Figure 2.8

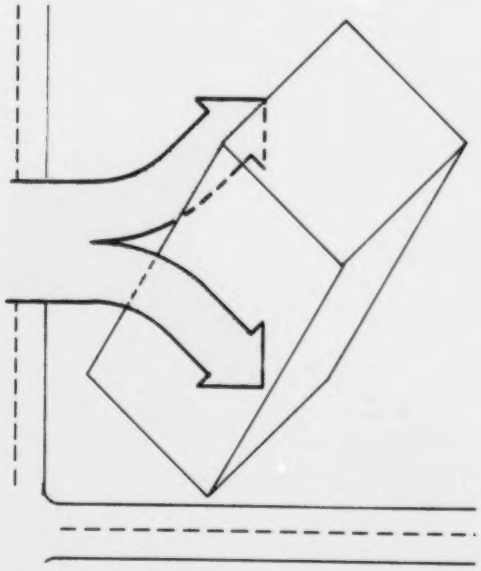


Figure 2.9

Building Shape and Massing

Rectangular buildings with a main face rising clearly from ground-level to any of the unshielded prevailing winds are problematic at the level of the street. Such configurations are a direct cause of wind-related problems experienced by pedestrians.

To reduce the adverse effects of building-induced wind turbulence a designer can:

1 Place the building on a podium (**Figure 2.6**) so that the lower floors deflect the downwash before it reaches ground-level.

2 Set a single building or a series of buildings in a pyramidal configuration (**Figure 2.7**) so that the lower structural masses will assist in sheltering taller building masses.

3 Consider circular or near-circular building forms which promote lateral wind flow and induce very little downwash (**Figure 2.8**), although wind speed is increased when the air flow detaches from the edges of the building. Because downwash is nearly eliminated by circular forms, they can be effective when sited in open areas or adjacent to low-rise buildings.

4 Turn the building 45 degrees on its axis (**Figure 2.9**) so that the narrow facade of the building is in the direction of the worst winds (which, in Calgary, commonly arrive from the north and west: see **Awareness, Figure 1.5**).

Figure 2.6 A podium deflects wind downwash before it reaches street level.

Figure 2.7 A pyramidal configuration promotes less direct wind exposure of the building face and deflects downwash winds.

Siting

The siting of a building should reflect a climatically sensitive approach to planning and design. However, wind alone cannot influence urban form in Calgary. A second, fundamental requirement to a sound planning and design strategy is exposure to the sun, both direct and reflected.

For example, a building that is well situated with respect to the sun will receive maximum benefits from insolation while minimizing its shadowing effect on surrounding buildings (**Figure 2.10**).

The integration of both solar and wind considerations is fundamental to good siting practice. As Calgary's prevailing winter winds are from the west and north during the winter months, it is possible to site a building in a manner that reduces adverse wind effects while capitalizing on low winter sun angles for increased insolation levels.

Because the amount of solar heat gain and the penetration of sunlight through window glazing is a function of how a building is sited, the angle and azimuth of the sun during the winter season (see **Awareness, Figure 1.7**) are important considerations in the design of building details (e.g., windows; see **Building Details**).

In the Calgary region, it is necessary to consider the immediate building site as well as the location of the site within the city. Calgary consists of a variety of landforms that influence the mesoclimate. Thus, the location of a building site within the city, whether it be on a Bedrock-Cored Hill or in a River Valley, is a critical factor in the design of that building. The existing street form and other building-forms can influence the mesoclimate and, ultimately, the microclimate of the building site. For example, how wind is directed down a grid-street in downtown Calgary should influence how a building will be designed and positioned on its site.

Summary

This chapter illustrates the necessity to consider not only how a building's form interacts with the climate, but what type of interaction occurs when buildings come together. The microclimate of the building site is therefore not determined simply by the configuration and siting of one building, but by adjacent buildings as well. The next chapter, entitled **Relationships Between Built Forms**, deals explicitly with these concerns.

Figure 2.8 A more circular building forms decreases downwash winds, but disperses them laterally.

Figure 2.9 Rotating a rectangular building 45 degrees on axis reduces downwash effects from north, west and south winds.

Figure 2.10 A building which maximizes solar access while minimizing wind exposure. The building steps down to the north to deflect wind and at the same time lessens the shadows cast on neighboring buildings. Morning and afternoon sun catches are provided with a passive screen deflecting western downwash winds. Low sun angles in winter can penetrate the canopy while summer shade is provided.

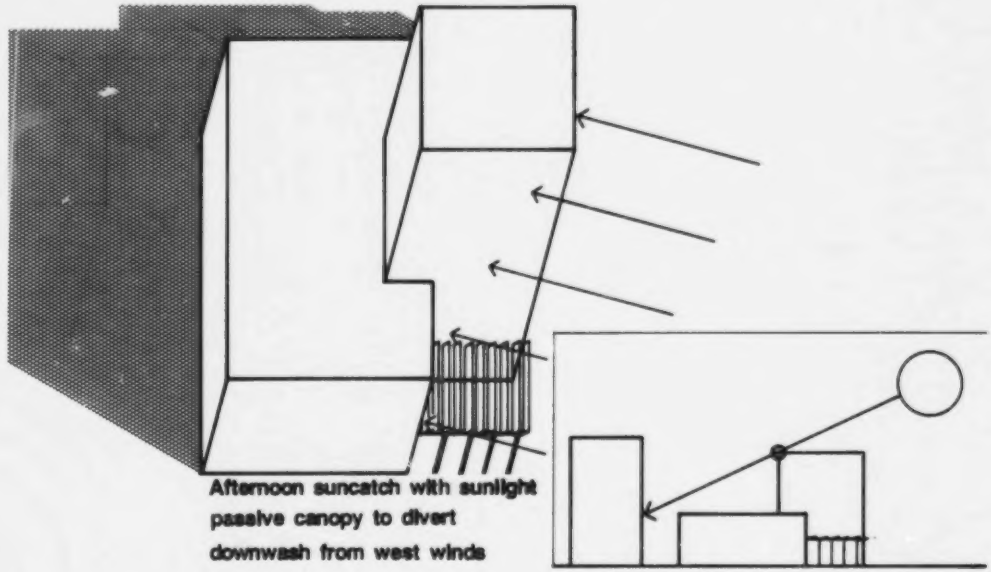


Figure 2.10

Figure 2.11

RELATIONSHIPS BETWEEN BUILT FORMS

The preceding chapter describes the relationship between the configuration of a building and the winter climate. However, since buildings are seldom isolated but rather are situated adjacent to one another, it is necessary to examine how climate is modified when buildings come together.

The relationship of a building to the buildings and spaces near it has an important effect on street-level wind, shadows, sun access, and the type and quality of public or pedestrian space in the building's vicinity.

High-Density Urban Areas

Urban form modifies climate and predetermines the microclimatic conditions of a building site (see **Awareness**, p. 1-14). The flat river flood plain that exists in the downtown core of Calgary has always been the area of the greatest concentration and intensity of urban development (**Figure 2.11**). In addition, spatial growth patterns in this area have followed a north-south, east-west rectangular grid pattern of streets.

Figure 2.11 Figure-ground relationship of downtown Calgary demonstrates the high intensity of urban development along an orthogonal grid street system.

Wind Effects

The interaction between the towering buildings found in Calgary's downtown core and high-speed winter winds frequently produces treacherous street level conditions (**see Building Configuration**, p. 2-1). The various high- and low-pressure wind areas around these buildings interact in complicated ways to affect wind speed and direction. In this way, the size, shape, orientation and spacing of buildings can significantly modify local wind characteristics.

For example, when two tall buildings are on opposite sides of a street lined with low buildings, the wind in the street itself can move from the high-pressure area into the low. As a result, the local wind is perpendicular to the ambient wind direction.

The rectangular grid pattern of streets in downtown Calgary, with its characteristic building configurations, produces a number of wind-related phenomena:

1 Where buildings converge in the direction of flow, such as along the east-west avenues of downtown, wind speed is locally increased by channelling (**Figure 2.12**).

2 Where wind is forced through narrow passages in the direction of flow, such as between the street and Plus 15 bridges or subways beneath the CPR mainline, wind speeds are increased. This is called the Venturi effect (**Figure 2.13**).

Eddies and vortices are induced by a building's corners. This may be evidenced by small funnel-shaped swirls of snow on the downwind side of a street corner where a building forms a significant edge. The drifting and swirling snow is then deposited in doorway recesses, drifted on open plazas, encrusted on sign posts and light standards and becomes packed into an icy crust on streets and sidewalks.

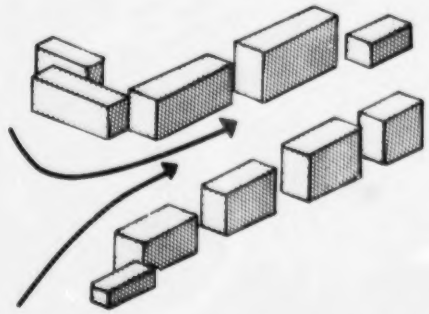


Figure 2.12

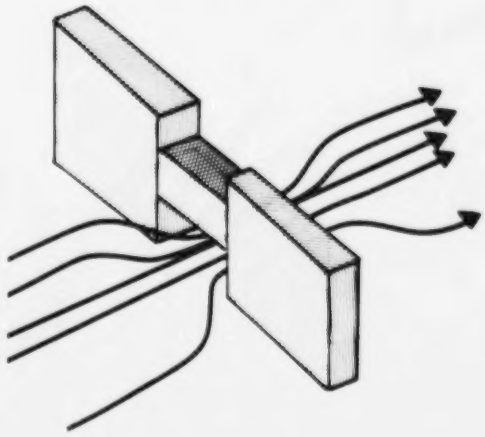


Figure 2.13

Figure 2.12 An increase in wind speed results as wind is channelled through buildings.

Figure 2.13 The Venturi effect caused by wind forced through narrow passages oriented to the direction of flow.

Figure 2.14a

Figure 2.14b

As a result of induced wind effects, Calgary's downtown can convert what is a winter squall for most of the city into a raging blizzard. Icy, snow-drifted sidewalks and plazas are much more difficult to negotiate when one is being buffeted by wind gusts which may be up to four times greater in velocity than the ambient wind. Snow, along with dust and other debris, when combined with wind, poses the greatest problem for pedestrians and motorists (**Figure 2.14**).

Figure 2.14 Snow and wind create pedestrian hazards. a) Slippery conditions on wind swept sidewalks and b) wind blown snow obscures signage and snow and ice creates overhead danger.

The direct relationship between heat loss and wind-chill is well documented (see **Awareness, Figure 1.4**). As temperatures drop, smaller wind velocities are required to bring about significant heat losses. In the downtown core, these effects are often magnified by increases in wind velocity. Readers are also directed to Lee and Kirby (1988), Calgary in Winter for further information regarding the influence of winter on human behaviour.

Given the conditions described above, it is necessary for a building designer to be familiar with the shape, height and orientation of any building that impinges on or defines a pedestrian environment. A designer must also be acquainted with the microclimatic conditions found at the base of these buildings (arcades, plazas, plinths, overhangs, etc.: see **Figure 2.15**).

Figure 2.15a

Figure 2.15b

Figure 2.15c

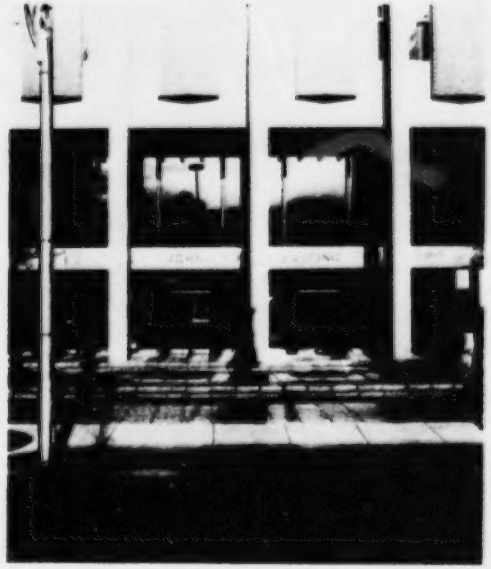


Figure 2.15d

Figure 2.15 Different building base conditions. a) arcade, b) plaza, c) canopies and d) recessed entries create a variety of microclimatic conditions.

Figure 2.16

Figure 2.17

The pedestrian environment around a building should be considered in the initial stages of design. The legal requirement for wind studies is a recognition of this fact. A range of actions exists for dealing with wind. They fall into two categories:

1 the partial enclosure (e.g., landscaping) or the total enclosure of pedestrian activity (**Figure 2.16**); and

2 the actual removal of affected pedestrian activity (**Figure 2.17**).

Figure 2.16 A Plus 15 demonstrates the total enclosure of pedestrian activity as a remedial measure in response to adverse weather conditions.

Figure 2.17 The Elveden Centre demonstrates the total removal of pedestrian activity at street level. The glazed interior space is a pedestrian route during inclement weather.

Because each windflow pattern is particular to a given area, the remedial action employed becomes a solution unique to that area. For example, the arcade at the base of the Hudson Bay downtown store is very successful as a climatic buffer between building and street (**Figure 2.18**). However, the same approach may be less successful if applied on the windward side of another building. Ultimately, the goal is to dissipate the energy of moving air and, in the process, reduce the likelihood of excessive snow deposits or other wind-related hazards. In this manner, landscaping and the judicious use of trees plays a vital role in the reduction of wind energy (**Figure 2.19**).

The total removal of pedestrian activity should only be a measure of last resort where remedial measures are either too complex or too costly.

Figure 2.18

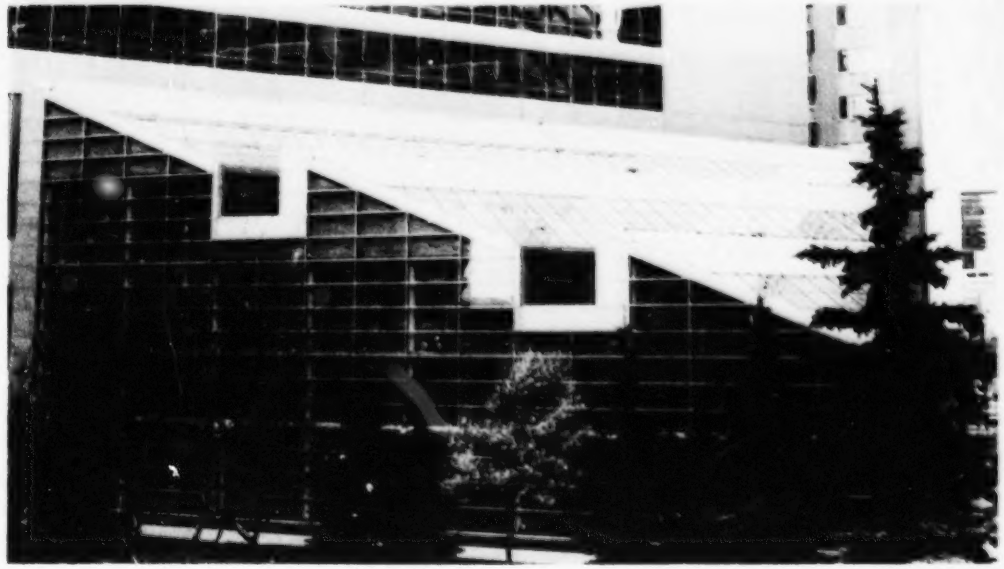


Figure 2.19

Figure 2.18 Arcade on the east side of the Hudson Bay store serves as a successful climatic buffer.

Figure 2.19 Trees can serve to reduce wind energy by deflecting wind before it reaches street level.

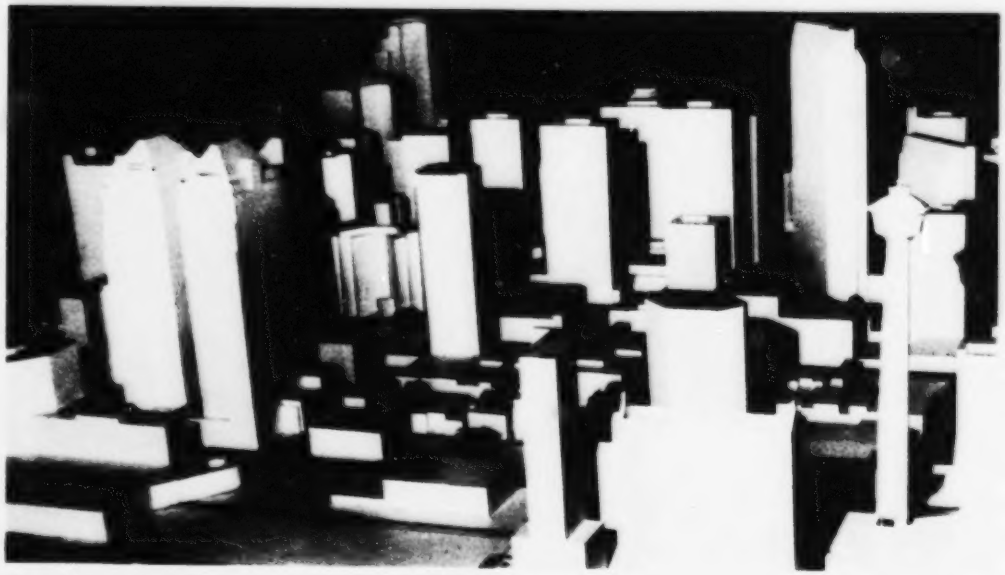


Figure 2.20

Figure 2.21

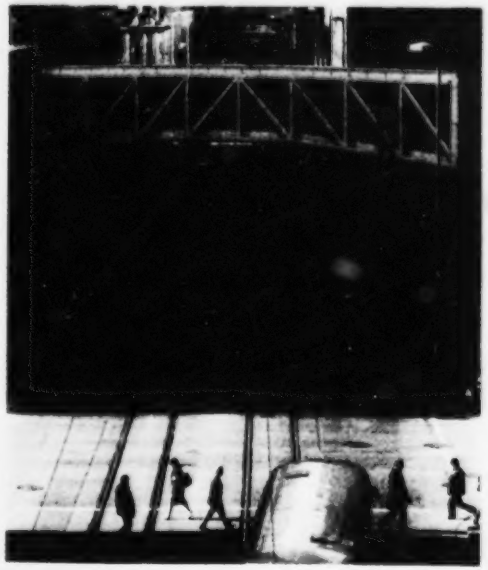


Figure 2.22

Solar Effects

An analysis or assessment of sunlight in downtown public spaces requires that the designer consider some key variables. An understanding of sun altitudes and angles, a profile of the street corridor and the relative reflectivity of surrounding building surfaces are vital to this assessment. Reflectivity will be affected by building geometries, horizontal and facade surface treatments and the angles of incidence of direct and reflected light. When assembled, these variables can yield a detailed description of shadows on streets and public spaces at a given location and at a range of times during the day and seasons.

Understanding sun effects is essential to recognizing the tremendous possibilities that exist for enhancing urban life during winter. Like wind, the extent of sun penetration can be studied using scale models. The City of Calgary possesses an excellent massing model for the downtown core which could serve as a powerful tool for such analyses (**Figure 2.20**). This degree of attention is justified wherever a tall building may influence the access of sunlight to surrounding buildings.

In northern latitudes, the sun is one of the most important factors governing the design of space for human

Figure 2.20 City of Calgary massing model of the downtown core.

Figure 2.21 Aerial photograph of downtown Calgary illustrating the extent of shadowing by tall buildings.

Figure 2.22 View along 7th Avenue SW showing the effect of overshadowing and that channels of sunlight occur at street intersections.

use. Sunlight deprivation has a markedly negative impact on human health, particularly in areas with prolonged seasonal light deprivation (see Lee and Kirby, 1988). As a result, the maximum amount of sunshine should be allowed to penetrate into the spaces between buildings.

Shadowing in built-up areas like Calgary's downtown (**Figure 2.21**) is extreme and is a result of the density and height of development. During the winter months when sun angles are low, over-shadowing of streets and other public spaces is almost continuous (**Figure 2.22**). To look down one of Calgary's east-west avenues at noon during the winter demonstrates that the only parts of the avenue receiving any direct sunlight are those areas intersecting with north-south streets. The rest of the avenue is dark and cavernous.

Calgary is blessed with amounts of sunlight that are enviable for a winter city (see **Awareness**, p. 1-5). To compensate for the inevitable loss of sunlight in much of the downtown core, courtyards, plazas and other public amenity spaces should not be viewed simply as left-over space on a site or as concessions for bonus-point density increases. They are opportunities to let sunlight into the downtown core. Designed well, such spaces can be important public gathering places, becoming ingrained in civic memory (**Figure 2.23**).

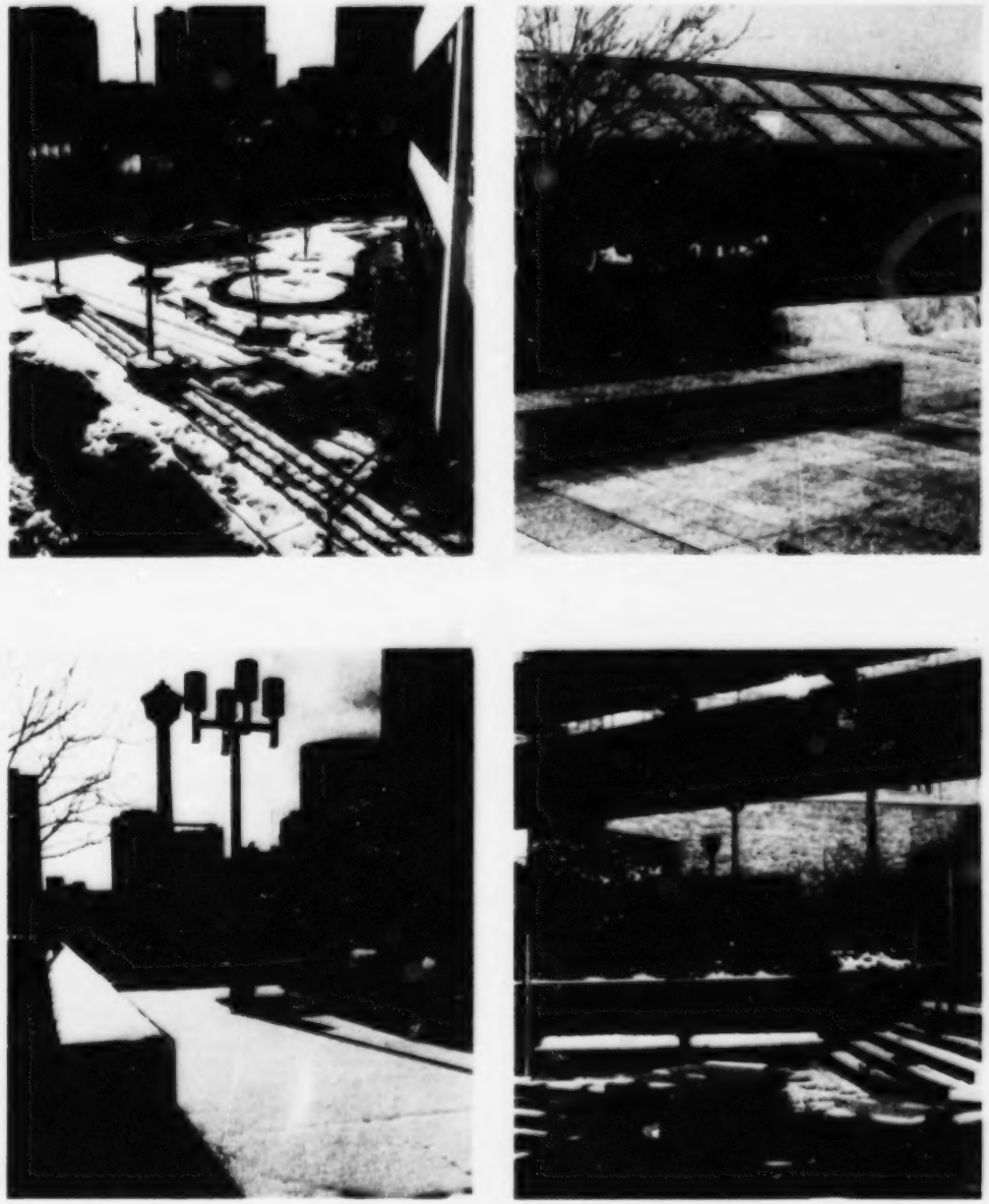


Figure 2.23 Four examples of public amenity spaces in Calgary which extend seasonal thresholds by capitalizing on good sun exposure, shelter from wind and relationships to pedestrian and vehicular movement.

Figure 2.23

Figure 2.24

Direct southern exposure is not essential to achieve a high level of solar access. The careful disposition of building elements can yield suitable combinations of direct, reflected and absorbed solar radiation while at the same time reducing wind turbulence. Places of this nature that already exist should be respected, especially by developments on adjacent sites, in order that they are not destroyed by overshadowing and wind deflection from neighboring buildings.

Likewise, solar radiation must be considered as a principal modifier of any design. Take, for example, an older, mixed-density residential area adjacent to the downtown core on the flat river floodplain. Here, buildings of radically different ages (and therefore technological sophistication), physical size, shape and height must coexist. Tall buildings in such areas often overshadow the older, lower structures, reducing the amount of sun penetration into the street (**Figure 2.24**).

The impact of sun, shadow and wind, as they are affected by collective building forms, have varied effects on snow accumulation and melting. For this reason it is important to consider surface materials and street furniture from the viewpoint of drainage, snow removal (be it mechanical or through selective wind scouring) and traction for pedestrian and vehicular traffic (**Figure 2.25**).

Piles of mechanically removed snow on sidewalk and plaza edges are common in Calgary following a snowfall. These mounds of snow, further affected by the wind and compounded by a permanently shadowed location, create a barrier to the street. As a result, street furniture, such as benches, parking meters and signage, are often rendered useless. These combined effects need to be anticipated at the planning and design stages in order to avoid such unmanageable consequences that in turn may lead to costly or unsightly remedial measures. Appropriate design solutions for street furniture warrants further attention than is possible in this manual.

Figure 2.25

Figure 2.24 Tall, high-density buildings in older, mixed-density residential areas can overshadow the older, lower buildings.

Figure 2.25 How snow is removed from the street can dictate the design and placement of street furniture.

Low Density Urban Areas

The orthogonal grid street system (see **Awareness**, p. 1-13) largely determines building orientation on north-south and east-west streets. The living room 'picture window' facing the street is a cultural custom in most North American neighbourhoods, but is often not optimal in terms of climate. However, it should be recognized that the desire to address the world in a formal way architecturally will often override climatic concerns such as the inefficiency of energy loss through large north-facing windows. Losses incurred should be off-set through other measures.

On east-west streets, narrow lots and building heights in many residential areas require off-setting measures involving modifications to the southern face of the dwelling. This is accomplished by allowing the sun to penetrate deep into the building cavity during the winter months when the sun's angle is at its lowest. Increasing the area of windows on the southern exposure also increases the amount of illumination and can reduce the overall energy requirements of the dwelling.

A similar approach to design can be adopted on streets oriented on a north-south grid. It is possible to create situations where the back and front parts of houses receive roughly equal amounts of insolation through skylights or clerestory windows that permit penetration of southern, midday sun into the center of the building cavity (**Figure 2.26**).

Measures that can be taken to attenuate or increase solar energy inputs include:

1 Using interior surfaces that reflect light deeply into interior spaces. Reflected sunlight has a pleasantly diffuse and even quality compared to the harshness of direct sunlight.

2 Modifying excess amounts of light with shades, curtains or blinds.

3 Regulating heat gain through the use of thermal mass such as masonry walls, concrete floors or any surface treatment that absorbs the sun's short-wave radiation and releases it in the form of long-wave, infrared radiation (**Figure 2.27**). This serves to soften the sun's thermal 'shock' during the day and extends its warmth into the cool winter evening.

These types of responses to site constraints are particularly suited to the tightly-spaced dwellings on narrow lots along flat, grid-iron streets found in Calgary's Beltline, Sunnyside and East Village areas. Medium and high-rise residential structures in these areas are becoming more and more common, especially in areas south and west of the downtown core. On east-west avenues, such buildings should be designed to allow as many units as possible with a north-south exposure. During the winter, a shorter sun path means that the north side of the structure will be permanently shadowed. Apartments that face only north must therefore rely on light reflected off buildings or landforms to the north.

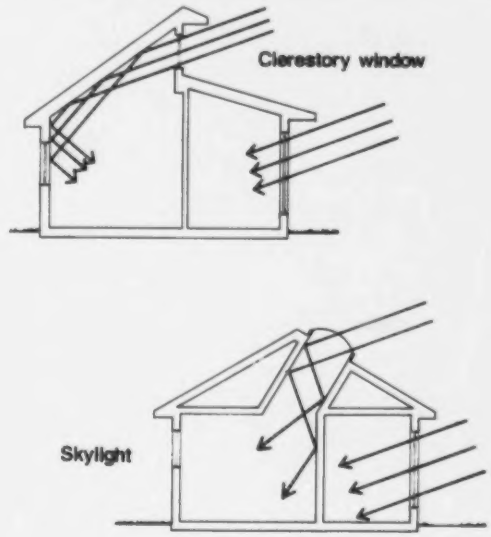


Figure 2.26

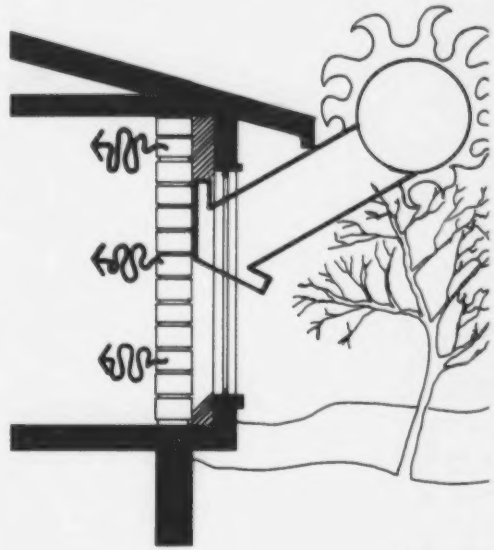


Figure 2.27

Figure 2.26 Clerestorey windows and skylights increase daylight into the building cavity with less heat loss than ordinary windows (Source: Alta. Dept. of Energy, 1987).

Figure 2.27 A passive solar space receives heat indirectly by a heat-absorbing concrete/masonry wall (Source: Alta. Dept. of Energy, 1987).

Figure 2.28

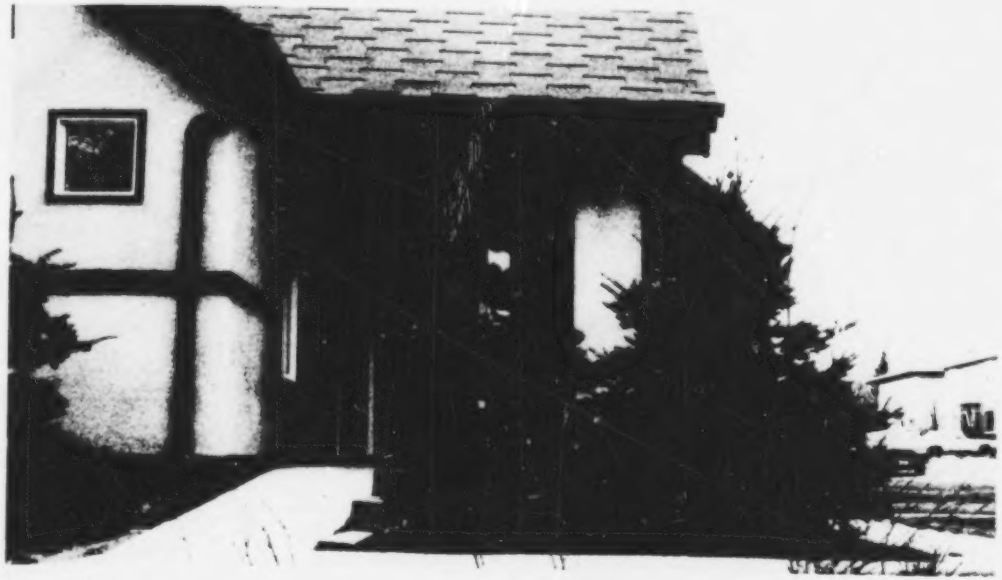


Figure 2.29

Calgary's "City Beautiful" residential areas (for example, Scarborough and Mount Royal) possess low building densities, large building set-backs and side-yards (**Figure 2.28**). Combined with sloping, hillside sites these areas require the same design considerations mentioned previously, but permit a greater latitude and variety of design solutions.

The role of landscaping (discussed in the next chapter) is of great importance in "City Beautiful" residential areas because of wide spaces between buildings. The combined effects of wind and snow may be more complex than on the grid streets, but opportunities exist for improving access to the dwelling while buffering points of entry from wind and snow (**Figure 2.29**).

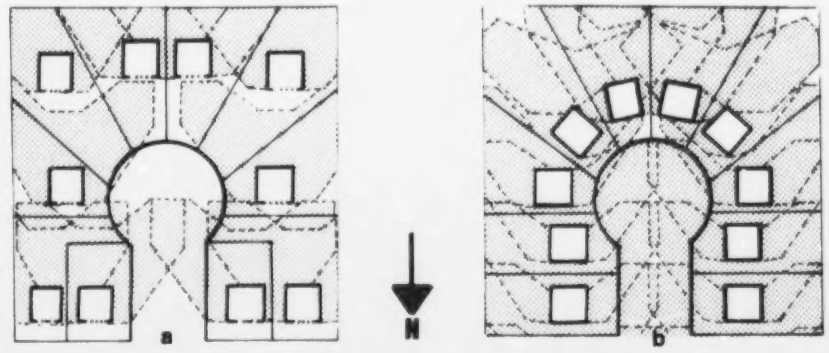
Figure 2.28 An example of a residential area within a distorted street grid system.

Figure 2.29 Landscaping can serve to buffer a dwelling entry from wind and snow.

Design considerations for the distorted grid, "City Beautiful" areas are likewise applicable to conditions found in the newer subdivisions built on a cellular street form. The most recent versions of these neighborhoods, typically along the Bow River Valley to the northwest and southeast and the Fish Creek and Elbow River Valleys to the southwest, make extensive use of cul de sacs connected by winding drives and boulevards. In many cases, opportunities for solar access are under-utilized in favour of even, symmetrical arrangements that closely follow the curve of the street. Alternative lot configurations need to be explored (**Figure 2.30**) to improve this situation (see Matus, 1988).

Summary

In discussing the interrelationships of collective building forms and the measures that may be taken to enhance microclimatic conditions on the building site, the discussion focuses on how buildings interact with the street. Suggestions are made regarding landscaping and building access to improve street level wind conditions and solar penetration. The next chapter follows with an exploration of building to street relationships.



Shadow casting analysis of a cul-de-sac (modified for solar access)

Figure 2.30a

Shadow casting analysis of a cul-de-sac (conventional design)

Figure 2.30b

Figure 2.30 Varying the lot configuration on cul de sac streets can a) maximize solar access, as opposed to b) traditional layouts (Source: Matus, 1988).

RELATIONSHIP OF BUILDING TO STREET

In this chapter the relationship of the building to the street is examined in closer detail. Specific approaches to winter design in terms of landscaping, building access, parks and public spaces are presented.

The landscaping of a building site can influence its microclimate. Each wall, walkway, hedge or park has the potential to alter the climate in its immediate vicinity. Great care should be exercised in the selection and disposition of these elements.

How landscaping elements are brought to bear on a particular climate control situation will be determined by wind, sun, precipitation and extreme temperature variations, and how these might affect the comfort or performance of those using the site.

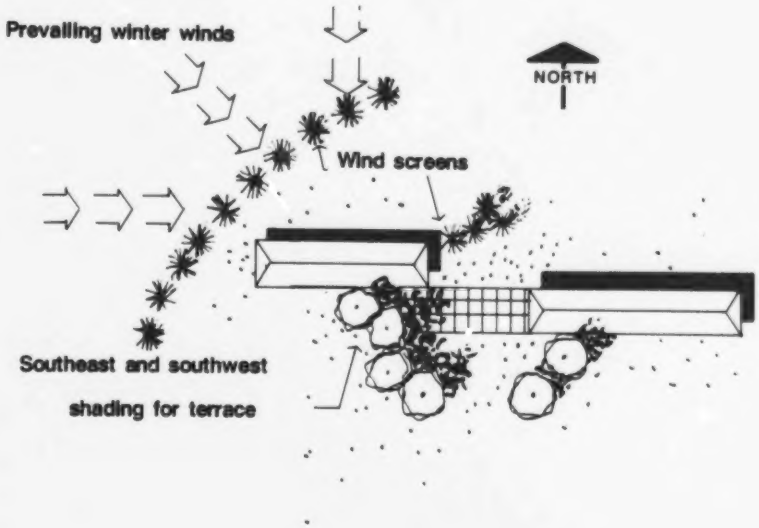


Figure 2.31

Figure 2.31 Landscape elements exert thermal control around buildings by deflecting winter winds and providing summer shade (Source: De Chiara & Koppelman, 1984).

Because wind has an influence on the real or perceived temperature, the control of wind is necessary in and around buildings. Landscaping aids in wind control by intercepting, directing or lessening wind effects (**Figure 2.31**) and involves several basic principles:

1 Plants control wind by obstruction, guidance, deflection and filtration. The degree of effectiveness depends upon the type of plant material used and its placement. Coniferous and deciduous trees can be used individually or in combination, or in conjunction with landforms and other architectural materials to direct airflow over the landscape and around or through buildings. A full description of the types of vegetation appropriate to Calgary's climate is provided in City of Calgary (1980), Proposals for Landscaping in Calgary - A Guide.

2 Shelter-belts and windbreaks are most effective when placed in a perpendicular line to the prevailing winds. The degree of protection and wind reduction depends upon the height, width and permeability of the plants used. The more penetrable the windbreak, the greater is the distance of protection behind the wind break. A penetrable wind break also inhibits wind turbulence (**Figure 2.32**).

3 Large conifers work particularly well in deflecting prevailing winds. Shrubs can be planted in front of coniferous trees to form a dense shelter-belt. Small trees and shrubs also provide wind control for the immediate area.

4 The most effective height-to-length ratio for wind breaks is 1:11.5. This provides the greatest possible shelter effect at the point furthest from the center of the belt. Air currents around the shelter-belt produce increased wind velocity at both ends of the windbreak. This may be alleviated by frequent gaps in the shelter-belt system.

Calgary's periodic Chinooks, accompanied by warm temperatures and brisk winds, cause rapid melting of snow and contribute to the desiccation of plants and to excessive soil erosion. Vegetation can be utilized to encourage snow accumulation and prevent rapid melting.

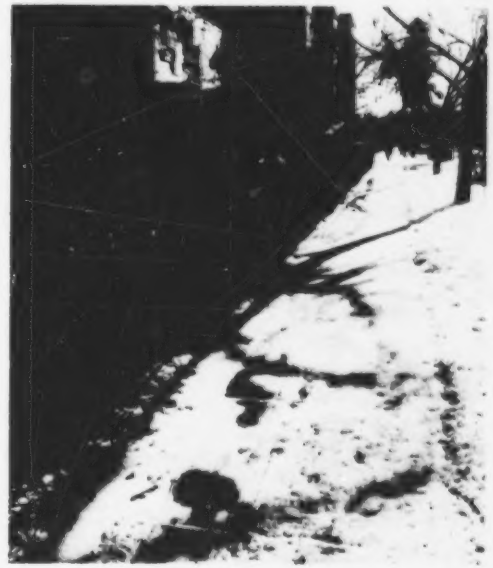


Figure 2.32

Figure 2.32 The hedge serves as a shelter-belt when placed perpendicular to prevailing winds. The permeability of the hedge reduces wind turbulence.

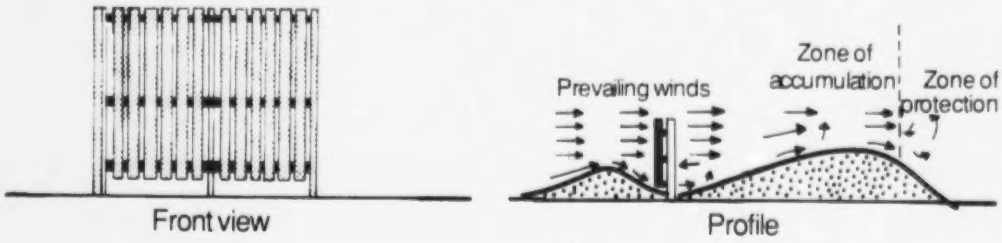


Figure 2.33

Figure 2.34

Some plants can be used as windbreaks that actually trap and retain snow. They accomplish this by imparting turbulence to the air moving through and over them, causing the air-borne snow to be deposited in and around the planting. Tall trees alone are not sufficient to initiate drifting; the inclusion of shrubs and other forms of ground cover in landscape designs aids in the retention of snow. Similar protection can be provided by certain types of fencing, if their height and permeability are carefully considered during the design phase (**Figure 2.33**). Designed well, planting can also reduce the cost of snow removal along lanes and parking lots (**Figure 2.34**).

Plants usually have a rougher, darker surface than most man-made materials and therefore reflect less solar radiation. Plants can also insulate buildings and the earth from the heat of solar radiation and abrupt temperature changes (**Figure 2.35**).

Visual glare due to the reflection of sunlight by snow or melting snow is a common problem in Calgary, especially with the low angle of the winter sun. Only evergreens provide year-round glare control in Calgary, although their effectiveness for many applications may be limited because of their slow growth and conical form.

Figure 2.33 Snow accumulation in the vicinity of a snow fence.

Figure 2.34 A well-planned planting scheme will reduce the amount of snow drifting on the parking lot.

Landscaping is another solution for designing protected and attractive entrance areas. Various landscaping techniques for improving the microclimate around a residential dwelling are illustrated in **Figure 2.36**.

Plants change colour seasonally and it is possible to provide splashes of colour for accent, interest or attraction throughout the year, even in winter. For example:

1 The bark of some deciduous trees and shrubs (e.g., the bright red of Coral Beauty Dogwood) provides visual interest against the white of a snow bank.

2 Many fruits (e.g., berries, crabapples) persist well into winter.

3 Certain small broad-leaved plants (e.g., Silver Willow) retain leaves while dormant maintaining their silver or rust colour.

4 Evergreens (e.g., spruce, pine and cedar) maintain their variety of blue and green tones.

The selection of hard landscape materials (e.g., planters, paving stones, etc.) warrants an equal amount of attention, especially in regard to their surface finishes, durability and maintenance requirements. For example, some surface materials can inhibit the accumulation of ice on walking surfaces, thereby reducing the need for continual maintenance and repair. A summary of suitable hard landscape materials for the Calgary winter climate can be found in City of Calgary (1980), Proposals for Landscaping in Calgary - A Guide.

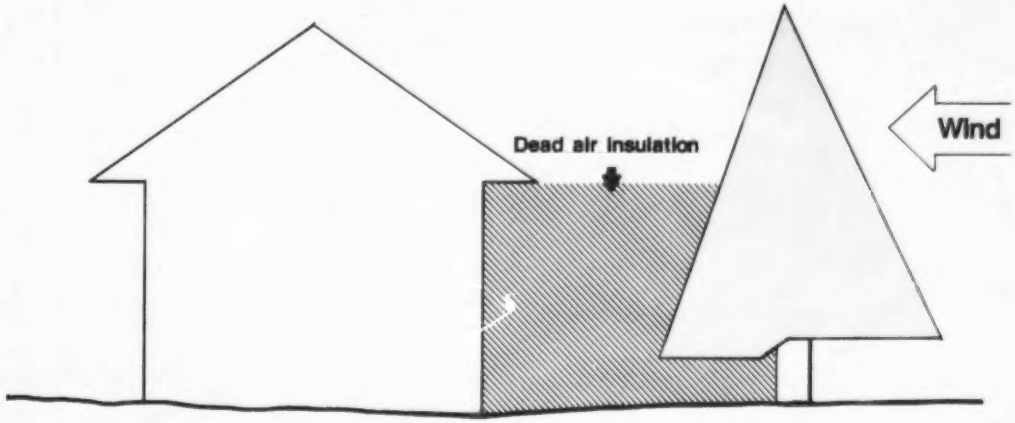


Figure 2.35

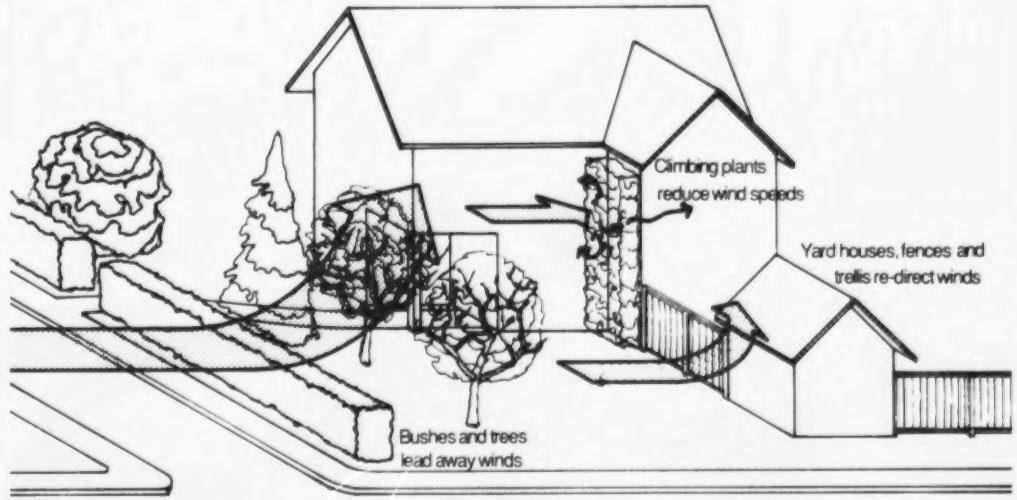


FIgure 2.36

Figure 2.35 Plants can serve as insulation to a building from prevailing winter winds.

Figure 2.36 Various landscaping solutions improve a building's microclimate.

Figure 2.37

Figure 2.38

Street Access and Servicing

The building site and the orientation of the street influence access to a building. Building sites can be designed to alleviate adverse winter conditions near a building. For example:

1 A north-facing driveway exposed to prevailing winds is prone to drifting snow and receives little sunlight (**Figure 2.37**). Locating a building's entrance or main driveway on the southern face of the building provides shelter from the wind and snow and makes snow removal and street maintenance an easier task.

2 Driveways and service areas vulnerable to the prevailing winter winds require landscaping, fencing or berming to provide shelter that will minimize the amount of drifting snow (**Figure 2.38**). Likewise, the location of a building's driveway or approach must be considered in terms of adjacent landscape and site features.

3 Sloped driveways, walkways and other types of site access can be particularly treacherous in winter. Care should be taken to maximize sun access (and thus melting) by the thoughtful choice and placement of landscape elements. Alternative surface materials may also help. Asphalt absorbs heat far better than concrete and exposed aggregate concrete has a rougher surface than standard concrete finishes. As a last resort, an alternate entranceway may be necessary on steep sites particularly prone to icing.

Figure 2.37 A north-facing driveway on which snow has collected and refuses to melt.

Figure 2.38 A driveway/service area protected from prevailing winds by a shelter-belt and berming.

A slight film of snow or ice can make for treacherous walking conditions. Pedestrian access corridors to buildings thus require nonslip surfaces (see **Building Details**). In addition, the performance of the material chosen and the method of installation (i.e., frost resistant construction methods) can reduce maintenance costs and provide a safe, trouble-free walking surface. For example, air entrained concrete reduces frost damage in areas severely exposed to standing water and de-icing salts.

The cul de sacs and winding street patterns of the newer residential subdivisions set up microclimatic interactions that are much more complex than those experienced in grid street pattern neighbourhoods. Because any given area possesses a wide range of building orientations, shadowing, sun access and wind effects can be manifested in any number of ways. Careful consideration of the possible negative effects of street, lot and building orientation should be made during the planning and design stages of subdivisions. The flexibility of possible street arrangements in subdivisions permits urban designers and planners to make design and policy decisions that give climatic factors a high priority (**Figure 2.39**). Matus (1988) provides an excellent analysis of street forms as they relate to climate.

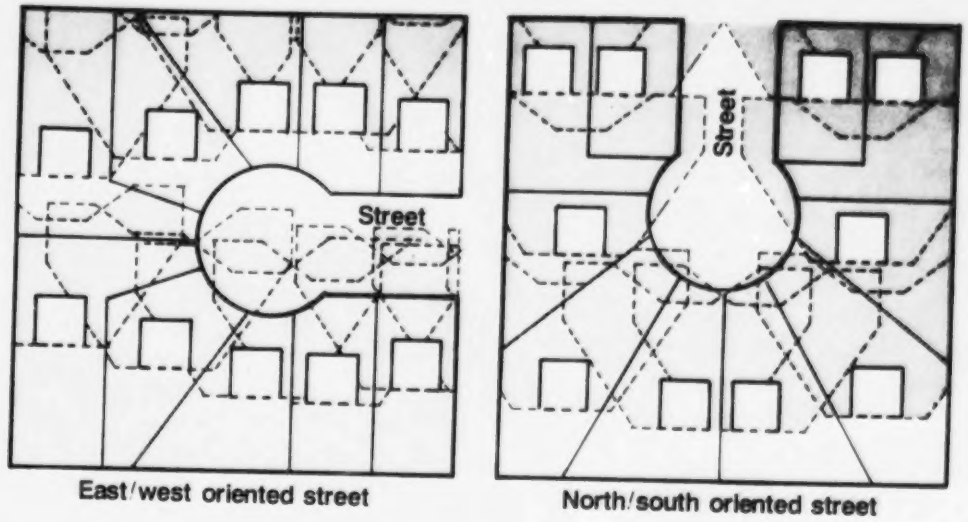


Figure 2.39

Figure 2.39 Alternative lot configurations can maximize solar access and allow snow to melt on the street surface (Source: Matus, 1988).

Figure 2.40

Figure 2.41

Parks and Public Spaces

Parks and public spaces are often under-utilized in winter. Large open exposures tend to be windswept and cold when the weather is inclement.

Outdoor courtyards provide one possible alternative to the unsheltered urban and suburban parks common in the city. They are more protected from wind and surrounding buildings provide radiant heat and access to indoor warmth. Courtyards are probably most pleasant and functional in areas with low-rise apartment complexes and other medium-density building types. (**Figure 2.40**)

Most urban parks will provide more attractive and comfortable environments for winter as well as summer when they are more densely planted with shrubs and trees, including evergreens (**Figure 2.41**). Trees planted to create the protective cover of a woodland, instead of the typical isolated specimens, are suggested. Coniferous windbreaks used along pedestrian ways provide shelter and control drifting snow.

A good example of an outdoor urban park is located south of Calgary's Municipal Building (**Figure 2.42**). The space is oriented to the south and receives direct solar access. In addition, it is sheltered by the Plus 15 extending over Macleod Trail to the west and by the Calgary Municipal Building itself from the north. It is a space that could still be better landscaped to protect people from the adverse elements of winter while allowing them to enjoy the warmth of the winter sun.

Figure 2.40 A courtyard created by an apartment complex serves as an outdoor social space.

Figure 2.41 The dense, natural planting of this ravine was retained by the developer as an aesthetically pleasing, sheltered park that invites use even in inclement weather.

Children are the most adaptable and imaginative users of winter environments. Yet, in winter, most of the recreational opportunities for children tend to be more fortuitous than planned. Playgrounds that are adequate in summer may be unusable or even dangerous in winter (e.g., no shelter from the wind or hazardous obstructions on slopes used for tobogganing). More thought is necessary to design playgrounds for all seasons. Good siting in relation to prevailing winds and adjacent buildings, the use of colour in playground furniture and a good landscaping scheme can make these places more inviting and pleasant during the winter. The addition of supplementary lighting encourages after school activities and extends the life of playgrounds and parks.

Mass plantings of shrubs or low trees such as sumac, dogwoods or cedars add colour and texture to the winter landscape, attract birds and other wildlife and improve the microclimate. Tall meadow grasses and the seedheads of herbaceous flowers will provide wildlife habitat throughout the winter. These approaches to landscaping could benefit a wide range of open spaces, including parks, university campuses, golf courses, utility right-of-ways and roadsides.

In addition to more creative plantings, open spaces are made more interesting and comfortable in winter by using structures and artwork. For example, fences or walls can reduce windchill and create suntraps; brightly coloured furniture and lighting can enhance the environment throughout the year. The **Building Details** chapter which follows discusses some of these items, but further study is warranted.

Summary

Many design features at the street level can be utilized to ameliorate the adverse climatic effects of winter. Likewise, those aspects of winter that are pleasant in Calgary can be strengthened by careful building design. The following discussion regarding **Building Details** presents a set of such opportunities.

This chapter deals with the transitional areas that exist between built forms and the street. It has stresses that open spaces exist on a broad variety of scales, and with a large number of orientations, building types and exposures. General Landscaping is reviewed including specific solutions to common site conditions. Individual assessments of site constraints and opportunities should be made when applying solutions.

Figure 2.42 The outdoor urban park located south of the Calgary Municipal Building is well designed in terms of protection from the wind and exposure to the sun.

Figure 2.42

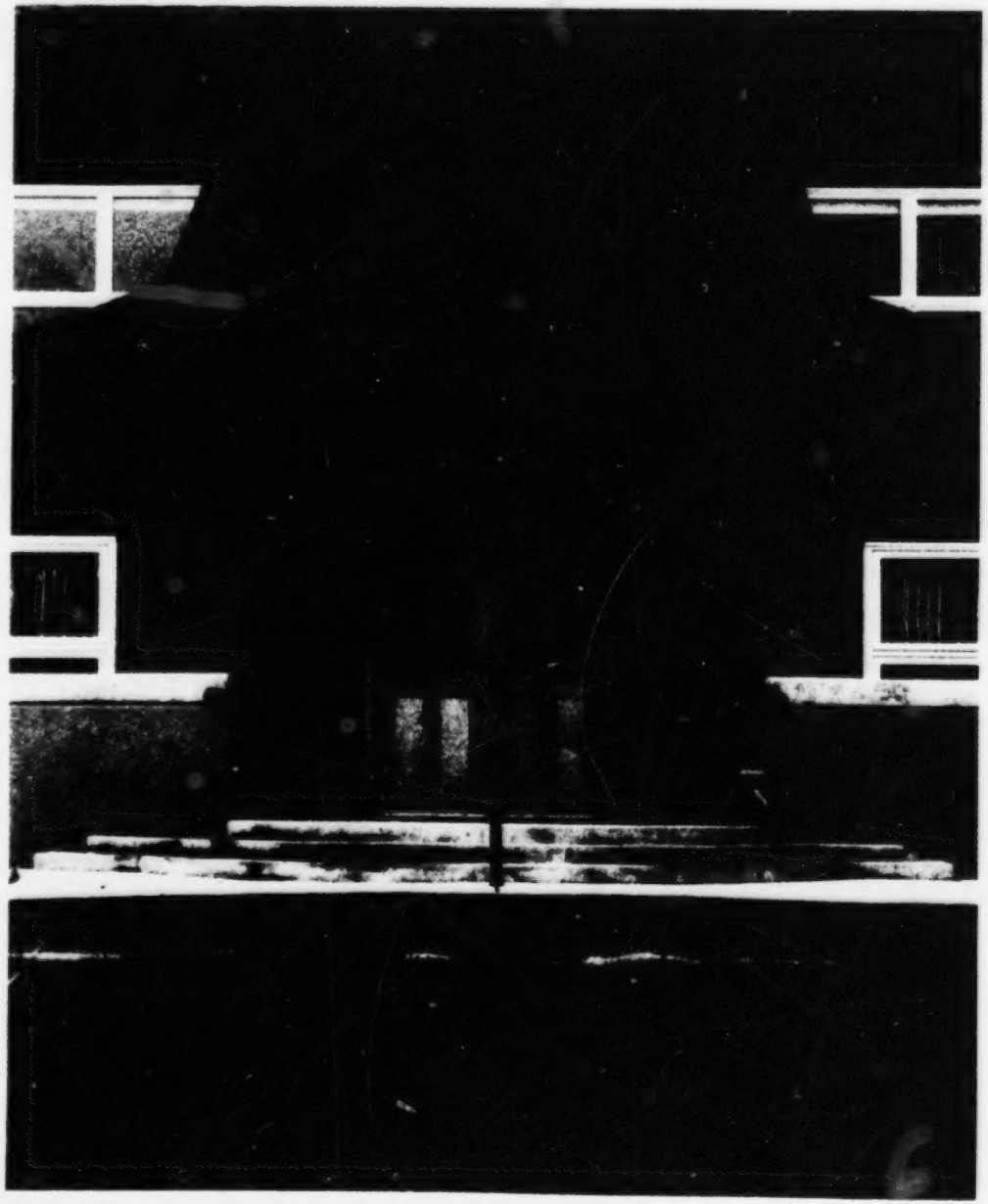


Figure 2.43

BUILDING DETAILS

This chapter provides an examination of the building features most directly affected by the winter climate and that can be most readily modified.

Entrances

In Calgary, entrances to buildings can be adversely affected by the wind, as well as falling and drifting snow, and thereby require shelter from these elements (**Figure 2.43**).

Figure 2.43 An example of a building entrance which is sheltered from wind and snow.

The predominant westerly and northerly winds are characteristic of Calgary's winter climate and must be taken into consideration when designing entrance areas. The orientation of major entrances is contingent upon many factors, including the orientation of the building and the conditions at the base of the building (see **Building Configuration**). Generally speaking, because of the strength and direction of the prevailing winter winds in Calgary, the south and the east are the preferred locations for major building entrances.

Some examples of entrance locations for east-west oriented streets are illustrated in **Figure 2.44**. Similar examples for entrance locations on north-south oriented streets are shown in **Figure 2.45**.

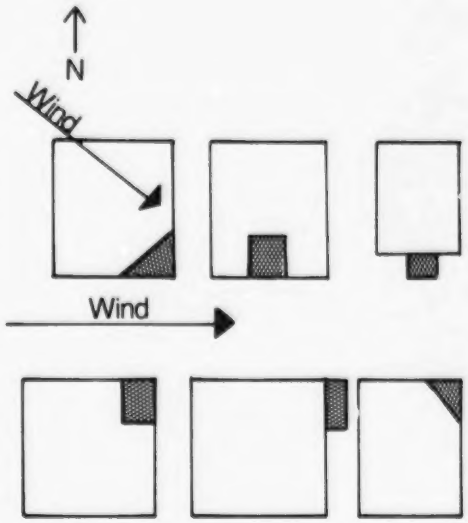
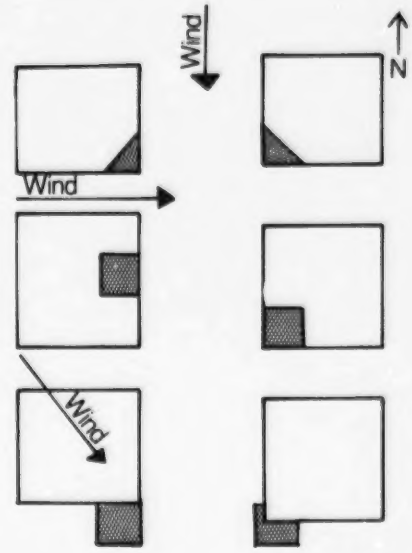


Figure 2.44



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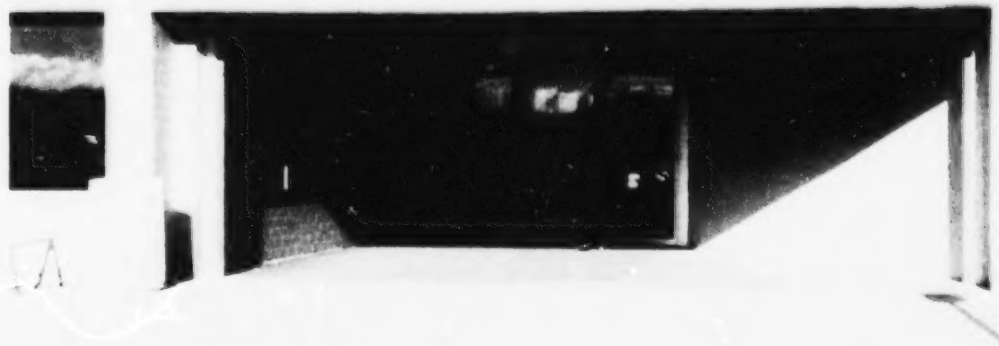


Figure 2.46

Figure 2.44 Examples of protected entrance locations on an east-west oriented street.

Figure 2.45 Examples of protected entrance locations on a north-south oriented street.

Figure 2.46 Fully recessing an entrance provides protection from wind and falling snow.

Figure 2.47

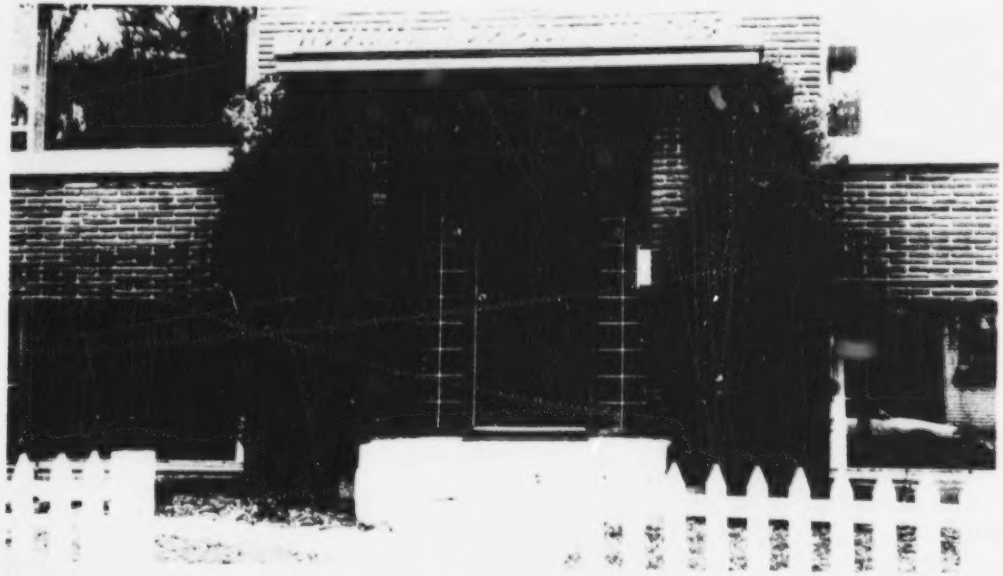


Figure 2.48

All building entrances, regardless of their orientation, require sheltering from the westerly and northerly winds. This can be accomplished in a variety of ways:

1 Fully recessing an entrance (**Figure 2.46**) provides protection from wind and falling snow. This type of entrance is highly recommended for south-facing entrances on east-west oriented streets and for east-facing entrances on north-south oriented streets.

2 An alternative to recessing an entrance area is to build a wall protruding from the sheltered side of the building (**Figure 2.47**). This type of entrance works well on the east side of buildings on east-west streets and on the south side of buildings on the west side of north-south streets.

3 Entrances can be partially recessed to provide shelter from wind and snow (**Figure 2.48**). These entrances are recommended for the same orientations as fully-recessed entrances. They are less effective than fully-recessed entrances and are recommended for areas less prone to severe conditions.

In many cases, locating an entrance on the corner of a building (**Figure 2.49**) provides some shelter

Figure 2.47 A wall provides shelter to an entrance.

Figure 2.48 A partially-recessed entrance provides protection from adverse winter conditions.

from prevailing winds. This is a particularly useful solution for buildings sited on the east side of a north-south street and on the south side on an east-west street, since street access normally situates the entrance in the path of prevailing winds.

Another possibility is to utilize a protective barrier, such as full or partial walls in front of a doorway, to deflect wind and snow (**Figure 2.50**).

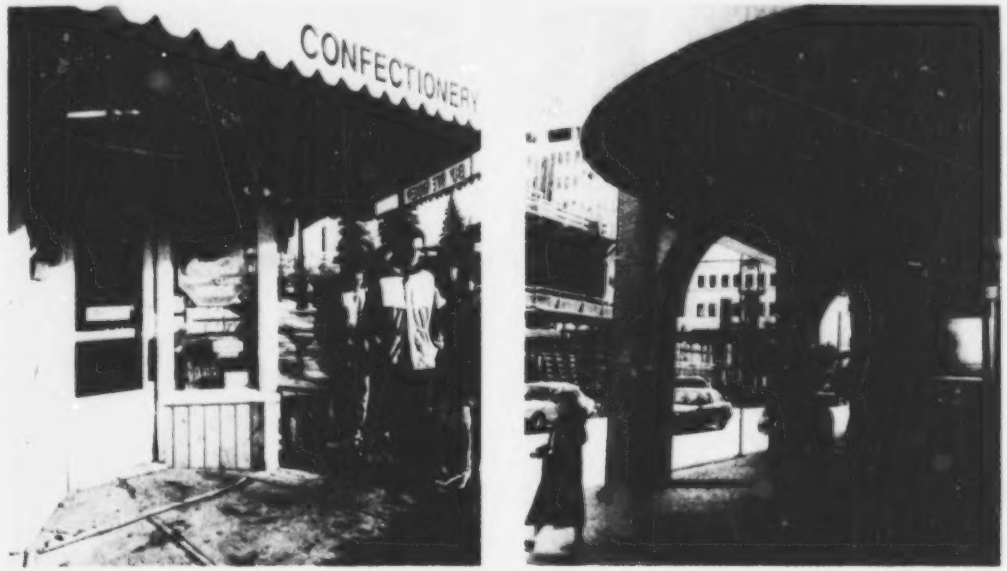


Figure 2.49

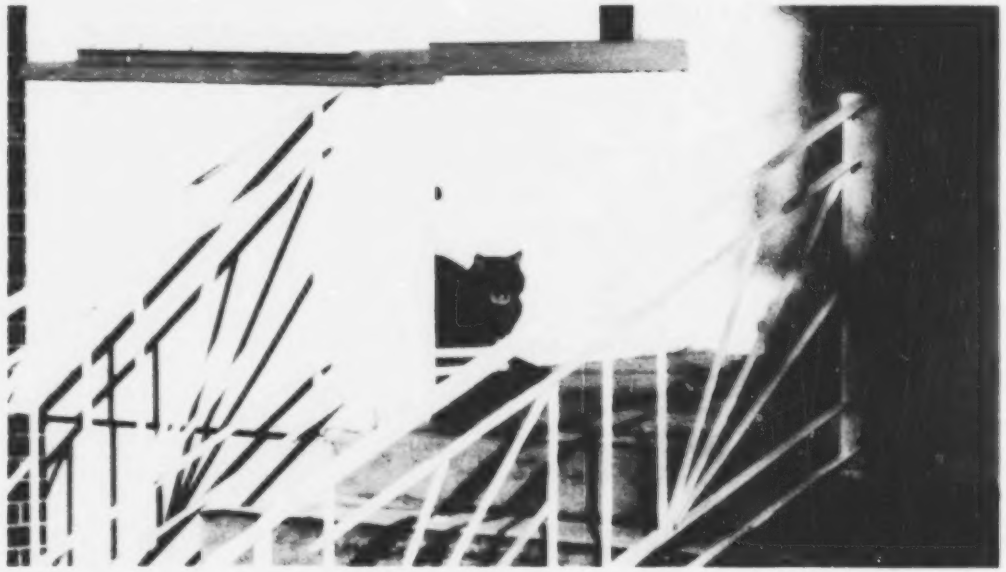


Figure 2.50

Figure 2.49 Two examples of corner entries which provide shelter from prevailing winds.

Figure 2.50 A protective barrier deflects wind and snow from an entryway.

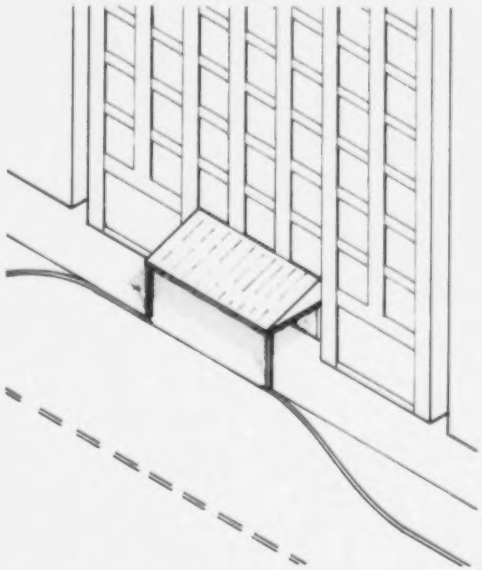


Figure 2.51

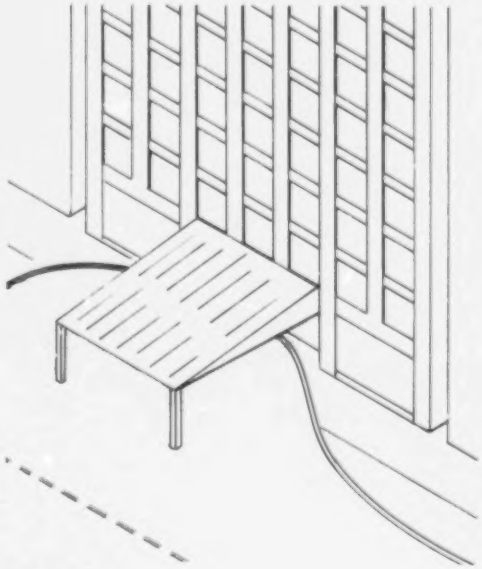


Figure 2.52

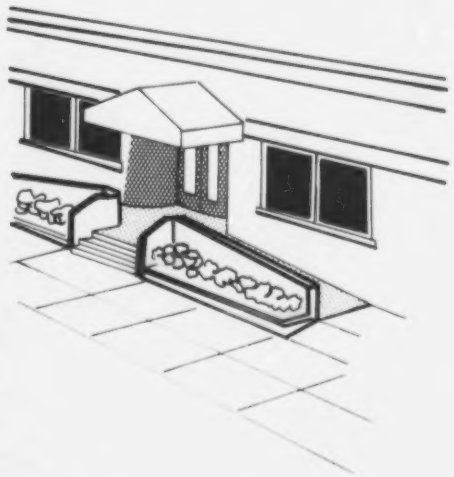


Figure 2.53

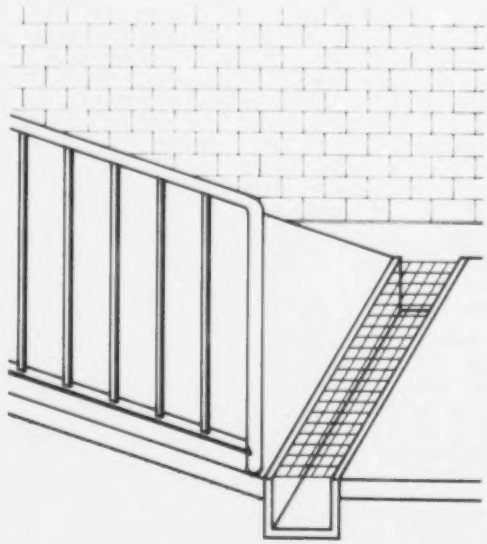


Figure 2.54

Covering a major entrance area with a canopy (**Figure 2.51**) protects the doorway from falling and blowing snow. In **Figure 2.52** the entrance is situated under a canopy directly in front of a driveway, enabling disabled and encumbered passengers to disembark and embark in a sheltered area free of snow and protected from the elements.

Pedestrian ramps (**Figure 2.53**) are common elements of major entrances and are sometimes the only means of access for individuals with physical handicaps. However, due to rapid melting and refreezing caused by Calgary's variable winter temperatures (see **Awareness, Figure 1.3**), ramps can become slippery with snow and ice collecting at their base. Incorporating a screened gutter at the base of the gradient (**Figure 2.54**) allows water to run off during these periods.

Paving pedestrian ramps with a darker coloured material causes solar radiation to be absorbed and promotes self-clearing of snow and ice. Ramps approaching an entrance can be protected behind "half walls" to reduce the effects of wind and blowing snow.

Figure 2.51 A canopy covering an entrance shelters the doorway from precipitation.

Figure 2.52 A canopy covered entrance and driveway enables passengers to disembark from their cars in a sheltered environment.

Figure 2.53 A pedestrian ramp can serve as a major access to a building.

Figure 2.54 A screened gutter at the base of a ramp inhibits the accumulation of meltwater.

Stairways, as well as ramps, must possess a continuous, even and slip-resistant surface. Adding these non-slip veneers to existing surfaces may be accomplished through tactile strips or through the use of textured paving materials.

Handrails should be constructed so that they are easy to grasp with heavy winter gloves. Dark coloured handrails promote rapid melting of snow and ice deposits and thereby become more comfortable to hold (**Figure 2.55**). Materials that are "warm" to the touch (e.g., wood) are also desirable.

Artificial light at entrances must be placed in protected areas, preferably recessed or under an overhang or canopy. Free-standing lights commonly can experience snow accumulation problems. If light standards are used, aerodynamic forms are recommended (**Figure 2.56**).

Entrances should have both natural and artificial illumination. An east-west street during the winter solstice is illustrated in **Figure 2.57a**, demonstrating how the shaded side of the street is illuminated by reflected light and a transparent canopy. **Figure 2.57b** illustrates how both sides of a north-south oriented street receive direct illumination during the winter solstice.

Figure 2.55

Figure 2.56

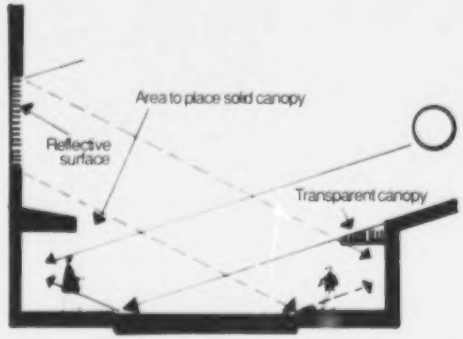


Figure 2.57a

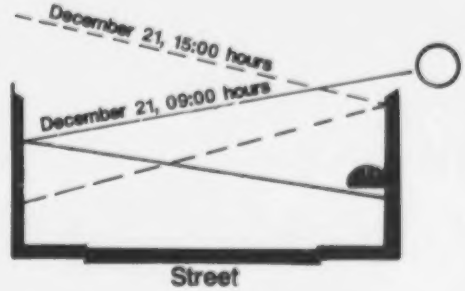


Figure 2.57b

Figure 2.55 Handrails which accompany stairways and ramps must be easy to grasp and set at the proper height.

Figure 2.56 The form of this light fixture will prohibit the accumulation of snow on its surface.

Figure 2.57 Obtaining natural illumination of canopied entrances during the winter: a) on an east-west oriented street, and b) on a north-south oriented street.

Figure 2.58

Figure 2.59

Figure 2.60

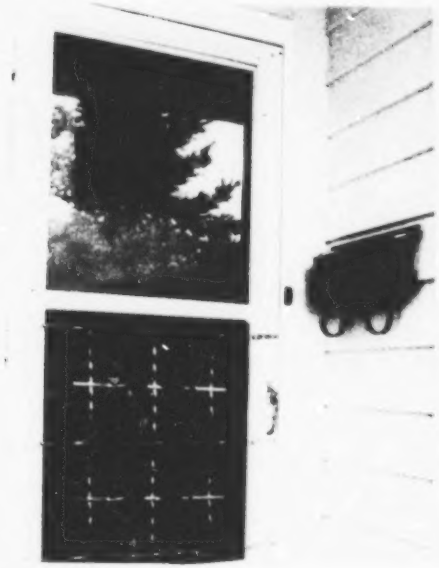


Figure 2.61

Doors

Swing-type doors contribute to building heat loss every time they are opened; revolving doors provide an air-tight entrance (**Figure 2.58**). An air-lock entry vestibule with two sets of doors, one set to the exterior and one set to the interior is another solution for air leakage problems (**Figure 2.59**). In residences, the connecting garage is an air-lock if the garage door is closed before opening the door to the house. Door frames should be designed and constructed for easy removal of snow and ice if exposed to the elements and should possess smooth surfaces without grooves (**Figure 2.60**).

Mail slots and keyholes located on entry doors leak air into buildings, especially during Calgary's extremely cold periods. Mailboxes on or beside the door are preferred (**Figure 2.61**). In fact, any metal hardware penetrating through the door, such as hinges, door knobs and locks, allows heat to escape from the building.

A foam insulated metal clad door provides more thermal insulation than a wooden door. Magnetic weather stripping seals a door to prevent rain entry and air leakage.

Figure 2.58 Revolving doors provide air tight entries.

Figure 2.59 An air lock vestibule which reduces building heat loss during winter.

Figure 2.60 A door frame designed for easy snow and ice removal.

Figure 2.61 Mailboxes which are separate from the door are preferred over mail slots.

Windows

Studies have shown that duration of sunlight is more important than intensity (Ne'eman et al., 1976). Maximizing the area of glazing on south-facing building walls provides the greatest duration and intensity of sun penetration and, therefore, heat gain (**Figure 2.62**). Heat gain and solar penetration should given careful consideration at the building design stage. Insufficient and excessive heat gain and solar penetration can both impair the function and enjoyment of interior spaces; optimal levels heat gain and solar radiation should be created instead. Ne'eman et al. (1976) provide guidelines for sunlight requirements in buildings for a variety of uses.

Locating patios or balconies with large glazed doors on the south side of a building creates an indoor/outdoor link (**Figure 2.63**). This extends living areas and takes advantage of warmer winter days. Glazing on a south building wall provides indoor greenhouse-like spaces and provides a sense of being outdoors (**Figure 2.64**).

Figure 2.62

Figure 2.63

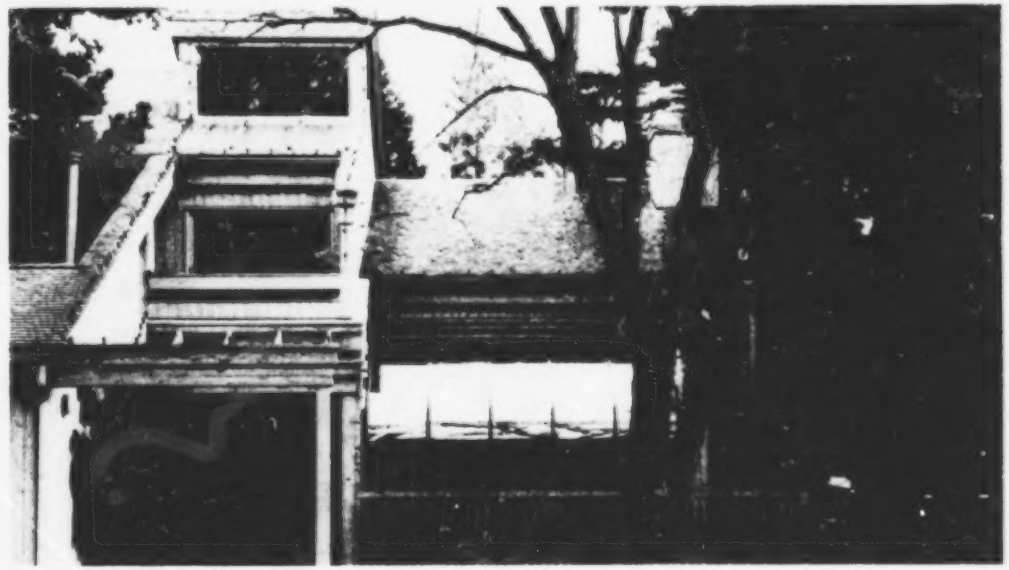


Figure 2.64

Figure 2.62 Building fenestrations on a south exposed wall encourage heat gain.

Figure 2.63 An extended indoor/outdoor link is provided by the glazed area on the second floor patio of this house.

Figure 2.64 An atrium located on the south side of a Calgary home.

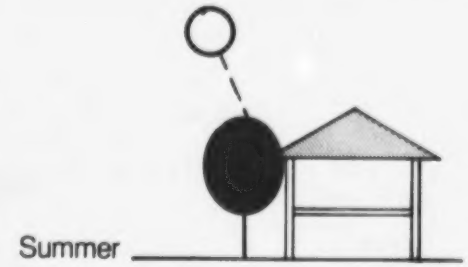


Figure 2.65

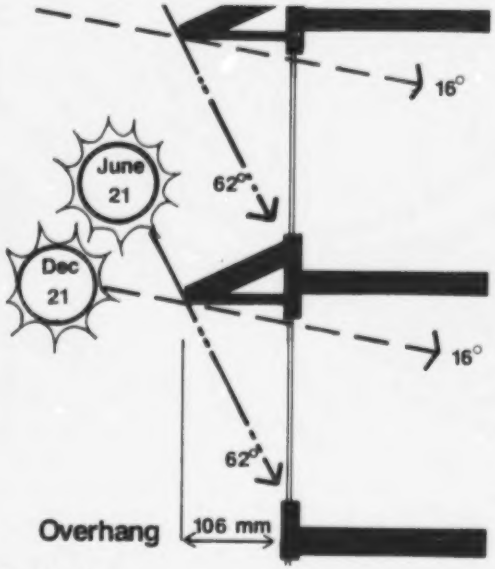


Figure 2.66

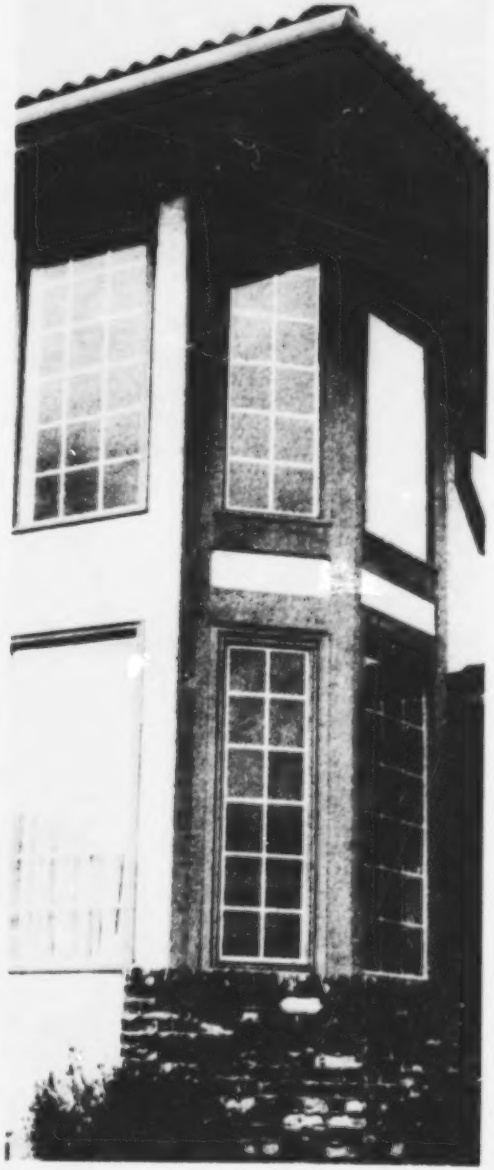


Figure 2.67

Extensive glazing on south walls may allow too much heat to enter a building during the summer months when the altitude of the sun is much higher. A deciduous tree located outside a window will provide shade during the summer, while permitting sun penetration during the winter (**Figure 2.65**). Alternatively, an overhang above the window can provide similar protection (**Figure 2.66**).

East- and west-facing windows receive significantly less sunlight during winter months than windows facing south. Light penetration can be maximized by the design of bay windows with south-facing elements (**Figure 2.67**). In summer, the morning sun penetrates the east window but does not require shading unless temperatures are extremely high. The low evening summer sun penetrates west-facing windows.

Figure 2.65 Deciduous trees serve to provide shade in summer and sunlight penetration in winter.

Figure 2.66 Windows with a fixed overhang will be shaded from summer sun, but receive the lower angle winter sun (Source: Alta. Dept. of Energy, 1987).

Figure 2.67 A bay window with glazed elements exposed to the south.

Skylights (**Figure 2.68**) capture the light fluctuations between east and west. Due to the usually limited accumulation of snow on roofs in Calgary skylights are a practical means of natural interior illumination and are particularly useful in getting natural light into north-facing rooms.

Northern windows receive reflected and diffused sunlight. If the building design has maximized interior lighting from the east, south and west, it is wise to minimize or eliminate north-facing windows (**Figure 2.69**).

Slat-type blinds (**Figure 2.70**), with slats wider than the gaps between them, adjust to intercept direct sunlight coming through the window. Slats can be positioned to direct the light onto a ceiling to add to the general illumination of the room. These horizontal venetian blinds should be placed inside the window or between the panes of double glazed windows.

As with doors, general considerations of window construction include sealing and minimizing metal mechanisms (e.g., hinges, locks and levers) that penetrate from the outside to the inside, conducting the heat with them.

Figure 2.68a

Figure 2.68b

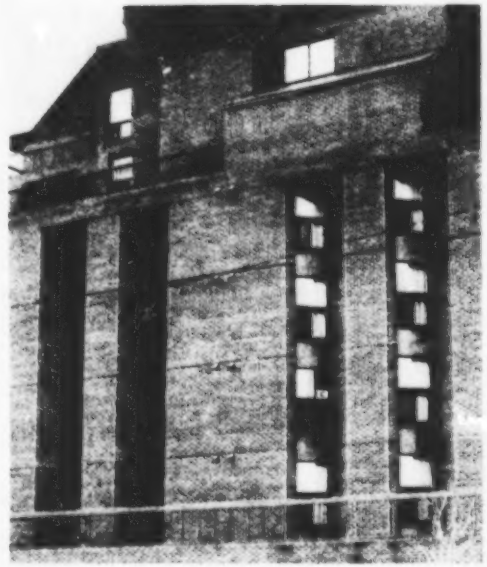


Figure 2.69

Figure 2.70

Figure 2.68 Two examples of building skylights: a) residential, b) commercial.

Figure 2.69 Northern windows on a building should be minimized.

Figure 2.70 Horizontal venetian blinds which can reflect light into a building interior.

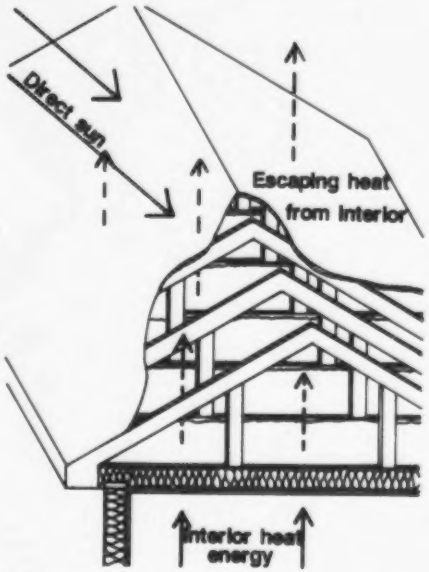


Figure 2.71

Roofs

The roof of a building serves to act as a barrier or selective separator between the internal environment and the external environment (**Figure 2.71**).

Interior-exterior temperature differences can be extreme and snow loads can strain structural members. Wind, solar radiation and escaping interior heat can complicate the function and the performance of a building's roof. Therefore, some general design principles regarding roofs must be considered.

Lean-to-roofs, canopies, balconies and porches situated below adjacent but higher pitched roofs are especially susceptible to heavy snow loading (**Figure 2.72**). Snow sliding off a higher pitched roof can settle on a lower roof, resulting in snow accumulations that are many times greater than accumulations at ground-level.

Flat roofs with projections, such as penthouses or parapet ("false front") walls can receive heavy snowdrift loads (**Figure 2.73**).

Depending on the direction and velocity of the wind, snow will settle according to the shape and aerodynamic qualities of the roof. In general, leeward slopes of a roof are susceptible to snow "drop out" resulting in the settlement of drifts, while the windward side is being swept clean. This phenomenon is most severe on portions of the roof leeward of vertical projections.

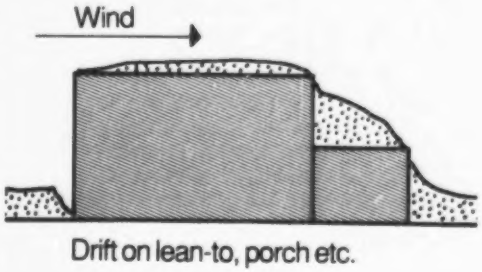


Figure 2.72

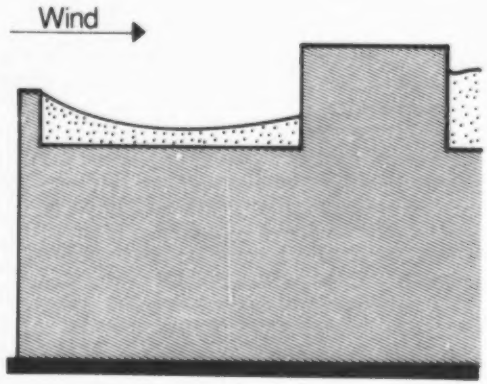


Figure 2.73

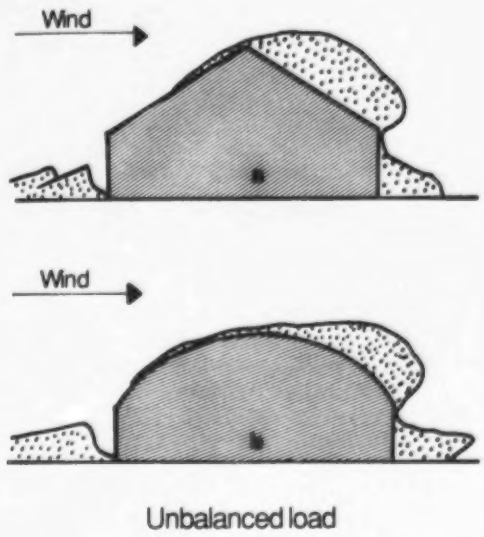
Figure 2.71 The energy dynamics of a typical roof system.

Figure 2.72 Snow loading on a lean-to roof located on the leeward side of a building.

Figure 2.73 Snow settlement behind a parapet or "false front".

Peaked and curved roofs may develop unbalanced snow loads when the wind direction is perpendicular to the ridgeline of the roof (**Figure 2.74**). Moreover, snow will more readily slide off roofs having slopes in excess of 30 degrees (**Figure 2.75**).

As a result of Calgary's frequent Chinooks, melting snow due to heat loss and insolation is a major design consideration. Heavy moisture laden snow may slide from a building's roof onto pedestrians. Meltwater may freeze to produce icicles which can be hazardous if they fall. Meltwater may also drip onto sidewalks of adjacent buildings and refreeze, creating slippery and dangerous walking surfaces (**Figure 2.76**).



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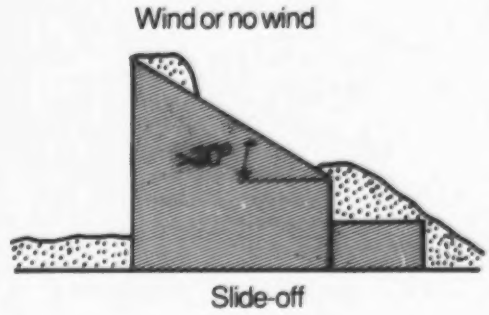

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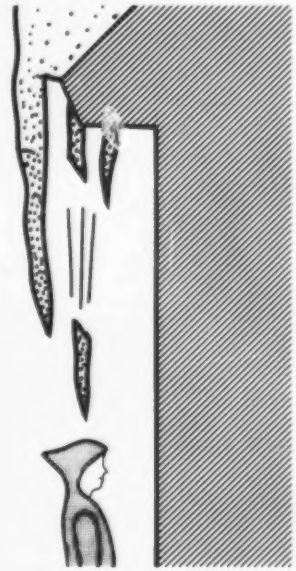

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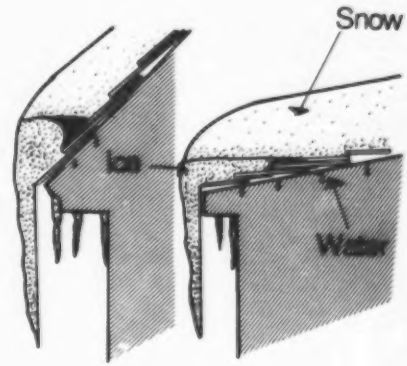

Figure 2.77

Figure 2.74 Snow settlement on the leeward slope of a curved roof and a peaked (Source: Canadian Building Digest, No. 193).

Figure 2.75 Snow will slide off a steep roof (Source: Canadian Building Digest, No. 193, 228).

Figure 2.76 Snow and ice melting on roofs creates icicles which can cause injury to pedestrians (Source: Canadian Building Digest, No. 89).

Figure 2.77 Ice damming at roof eaves with meltwater entering the attic space (Source: Canadian Building Digest, No. 89).

"Ice dams" may occur at the edges of sloped roofs (**Figure 2.77**). Melting caused by heat loss produces a water film between the roof surface and its blanket of snow. The roof surface at the eaves is less susceptible to heat loss and is therefore colder; when meltwater reaches this portion of the roof it refreezes. Ice can build-up, damming meltwater which may eventually leak into the attic space of the roof. Leakage into roof cavities will reduce the effectiveness of the building insulation, produce further heat loss, promote more damming, and can damage building structural components and interior finishes.

The best protection from ice damming is to insulate heavily to reduce heat loss and to substantially ventilate the attic space. Allowing ventilation above the insulation layer cools the roof surface enough to prevent melting, thus creating a "cold roof" (**Figure 2.78**)

Summary

The **Building Details** chapter provides specific guidelines for building features that can be designed or modified to respond to Calgary's winter climate. Information is provided on designing or improving entrances, ramps and stairways that are affected by wind and snow.

Recommendations for doors, windows and roofs depend on climatic conditions and local environments. This chapter could be expanded upon in the future to include outdoor furniture, signage, lighting, colour applications and other areas.

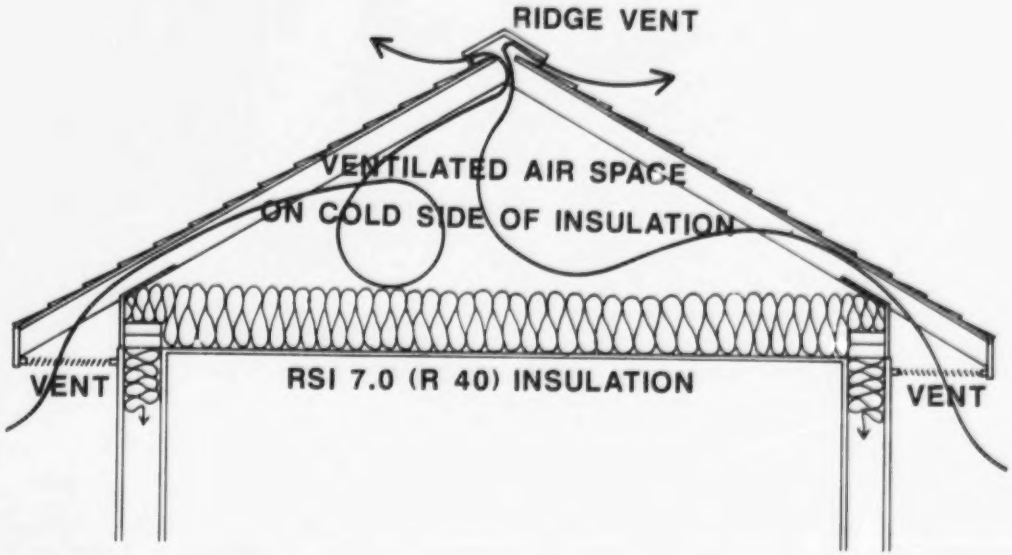

Figure 2.78

Figure 2.78 "Cold roof" construction prevents the formation of ice dams.

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GLOSSARY OF TERMS

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APPENDICES

TABLE OF CLIMATIC DATA

(Climatic Normals for Calgary International Airport)

Period	Element	Unit	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1951-80	Mean max. temp	°C	-6.0	-1.5	1.7	9.4	16.0	19.9	23.3	22.1	17.4	12.3	3.3	-1.8	
1951-80	Mean min. temp	°C	-17.6	-12.9	-9.6	-2.9	2.8	7.0	9.4	8.3	3.8	-1.3	-8.6	-13.8	
1951-84	Extreme max. temp	°C	16.3	18.9	22.8	29.4	32.2	35.0	36.1	35.6	33.3	29.4	22.8	19.4	36.1
1951-84	Extreme min. temp	°C	-44.4	-45.0	-37.2	-30.0	-16.7	-3.3	-0.6	-2.2	-13.3	-25.7	-35.0	-42.8	-45.0
1951-80	No. days with frost	days	31	27	30	24	7	•	0	•	5	19	28	30	201
1951-80	# days max. >0°C	days	11	15	20	27	31	31	30	31	30	29	21	16	292
1951-80	# days max. >18°C	days	0	0	•	3	12	19	27	25	14	7	1	0	108
1951-80	# days max. >30°C	days	0	0	0	0	•	1	2	2	•	0	0	0	5
1951-80	# days min. <-2°C	days	30	26	27	17	2	•	0	0	2	13	26	29	172
1951-80	# days min. <-20°C	days	12	7	4	•	0	0	0	0	0	0	2	8	33
1951-80	Mean rainfall mm	0.2	0.3	0.2	10.2	41.1	87.6	65.4	55.4	33.2	6.0	0.3	0.1	300.0	
1951-80	Mean snowfall	cm	20.8	19.1	19.9	25.9	8.4	1.9	T	T	5.9	13.5	16.3	20.8	152.5
1951-80	Mean total precip.	mm	16.2	15.5	16.1	32.6	48.7	89.4	65.4	55.4	38.2	17.6	12.7	16.0	423.8
1951-80	Most snow-24hrs	cm	25.4	27.7	24.1	45.7	48.4	24.9	0.3	6.1	22.9	29.7	35.6	21.8	48.3
1951-80	# days w/ snow	days	11	9	10	8	3	•	0	0	2	4	7	8	58
1951-80	# days w/ precip.	days	11	9	10	9	10	13	11	11	9	6	7	8	113
1951-80	# days snow > 1cm	days	6	5	6	6	2	•	0	0	1	2	4	5	37
1951-80	Degree days <18°C		922.9	713.6	681.6	441.5	265.8	141.7	68.8	98.5	223.8	386.6	620.3	799.9	5365.0
1951-80	Degree days >5°C		1.2	2.1	4.8	39.4	148.6	253.7	352.5	317.1	178.1	78.5	9.1	2.1	1387.2
1955-80	Average wind speed	km/h	16.2	15.0	16.4	18.1	18.2	17.0	14.9	14.4	15.8	16.3	15.4	16.1	16.2
1955-80	Prevailing winds		W	W	S	NNW	NNW	NNW	NNW	NNW	NNW	W	W	W	NNW
1955-80	Max. gust speed	km/h	127	126	114	116	121	109	122	109	101	115	113	111	127
1951-80	Bright sunshine	hours	102.0	127.9	162.2	204.9	253.6	267.0	322.2	282.3	194.7	176.0	123.9	97.7	2314.4

•	Less than one day	T	Trace	<	Less than	>	Greater than

GLOSSARY OF TERMS

Aspect - The orientation of a hill slope.

Chinook - A warm, dry wind developing from warm Pacific air masses. A Chinook is characterized by a sharp, discontinuous rise in temperature, a decrease in the relative humidity and the presence of strong westerly winds. An **elevated Chinook** traps colder air over the city and causes reverse air circulation, easterly winds and temperature inversion. **Surface** Chinook winds reach the ground surface and create warm, dry and windy conditions.

"City Beautiful Movement" - A movement originating in the United States which dealt with planning at the town or city scale. Its main purpose was to encourage community improvement through public gardens, boulevards and green spaces. Mount Royal is one example in Calgary of this movement's influence.

Cold air drainage - This occurs in areas of the river valleys where cool air from higher plateaus drains into the valley itself. Bridgeland and Bowness are areas in Calgary where this occurs regularly during the winter months.

Continental climate - A climate possessing wide daily variations in temperature and low relative humidities.

Cordillera - a parallel series of mountain ridges.

Downwash effect - a descending flow on the windward side of a building resulting from the differences of air pressure between high and low levels of a tall building.

Drag effect - Lowering of wind velocity by the ground surface. Winds at lower altitudes are slowed by the "roughness" of the ground surface (i.e., the profile of a highly built-up area).

Figure-ground relationship - A figure-ground drawing is a two-dimensional representation of the relationship between the placement of buildings and open spaces. Buildings (figures) are seen in black and the open spaces (ground) in white. The understanding of this relationship is important as buildings and the spaces between them contribute significantly to modifying the microclimate. At a small scale, this type of drawing will not show figures such as trees, fences, lamp posts, etc., which are minor modifiers of climate.

Glaciation - The marking or polishing of the ground surface produced by ice action during periods when the ground is covered with glaciers or sheets of ice.

Heat island - An area with significantly higher temperatures than the surrounding area(s) caused by an extensive concentration of buildings or a high rate of heat radiation from buildings.

Ice dams - Ice damming occurs at the eaves of a roof. It results from snow build-up on the roof melting at the roof surface. This occurs where attic insulation is inadequate in and around the soffit area and above the outside wall of the building. Heat from inside the building readily escapes through the poorly insulated attic to the roof surface, heating it and melting the snow on its surface. As the water progresses towards the eaves' edge, it cools and forms into ice. This repeated action creates an ice dam along the edge. Ice dams can be prevented by ensuring that these spaces are well insulated and that the roof membrane is not porous.

Insolation - The exposure of a surface to the sun's rays.

Landform Unit - An area of generally uniform and distinct landform characteristics. Boundaries between landform units are generally defined by significant changes in relief.

Macroclimate - The overall climate of a region. In Calgary, macroclimate is controlled by geographic location, regional atmospheric circulation and proximity to the mountains.

Mesoclimate - The climatic regime that governs a particular area. The boundaries and characteristics of the mesoclimate are determined not only by the climate of the larger region but also by the specific topography of the area, the character of the development in the region and other local characteristics.

Microclimate - The climate of a particular site. A microclimate is determined by the larger mesoclimate of the area and by building size, shape, orientation, trees, fences, street orientation, etc.

Reliable snow cover - 2.5 cm (1") of snow remaining on the ground for at least 7 days.

Reverse wind circulation - Where surface wind direction is opposite to the wind direction at higher altitudes.

Snow dropout - Occurs when snow build-up on a roof eaves becomes too heavy to support itself and slides off the roof or large amount are blown off the roof. Snow drop-out can also be caused by an increase in temperature causing snow to partially melt and slide off the roof.

Solar gain - An increase in the temperature of the air, materials and contents of a room as a result of the penetration of the sun's rays into an interior space.

Temperature inversion - When temperature decreases with altitude-the reverse of the normal trend. In Calgary, temperature inversions commonly form during an elevated Chinook. Warm Pacific air flowing over the mountains towards Calgary is at a high elevation, while a cooler high pressure air mass from the east is at lower elevations. The warm air above traps the cooler air, thus creating a temperature inversion. This remains until the Chinook forces its way down to lower elevations.

Topography - The description and representation of the surface features of a region including its relief and surface features such as rivers, lakes, roads, bridges, buildings, etc.

Venturi effect - An increase in wind speed caused by air flow being forced through a narrow passage located in the direction of the wind flow.

Vortex - A whirlwind produced when the downwash of air along the face of a building strikes the ground.

Wind-chill factor - A measure of the rate at which exposed flesh will freeze.

Wind turbulence - The flow of air having irregular variations in the course of time.

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